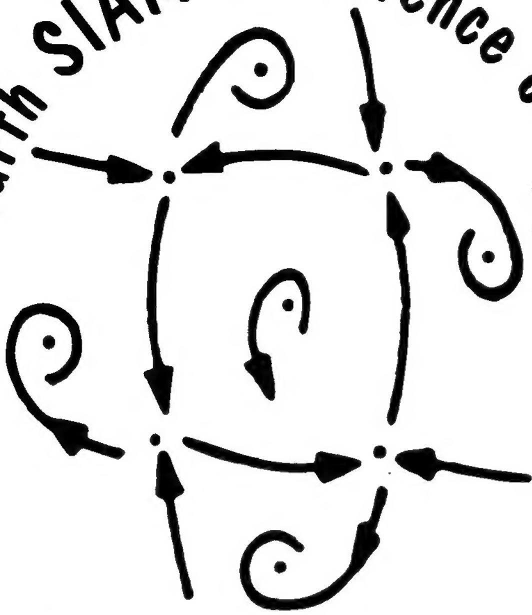
FINAL PROGRAM AND ABSTRACTS

Fourth SIAM Conference on APPLICATIONS of DYNAMICAL SYSTEMS



May 18-22, 1997

Snowbird Ski and Summer Resort • Snowbird, Utah

Sponsored by SIAM Activity Group on Dynamical Systems

Conference Themes

The themes of the 1997 conference will include the following topics.

Principal Themes:

- Dynamics in undergraduate education
- Experimental studies of nonlinear phenomena
- Hamiltonian systems and transport
- Mathematical biology
- Noise in dynamical systems
- Patterns and spatio-temporal chaos
- Synchronization

Applications in

- Aerospace engineering
- Biology
- Condensed matter physics
- Control
- Fluids
- Manufacturing
- Mechanics
- Oceanography
- Lasers and op
- Quantum chaos

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http://www.siam.org/meetings/ds97/ds97home.htm

Contents

Funding Agency

SIAM thanks the National Science Foundation and the Office of Naval Research for their support in conducting this conference.

Get-Togethers

Welcoming Reception

Saturday, May 17, 1997
6:00 PM - 8:00 PM

Poster Session I and Reception

Tuesday, May 20, 1997
7:30 PM - 9:30 PM

Poster Session II and Reception

Wednesday, May 21, 1997
7:30 PM - 9:30 PM

Organizing Committee

Mary Silber (Co-chair)
Northwestern University

Steven H. Strogatz (Co-chair)
Cornell University

Peter Bates
Brigham Young University

Charles R. Doering
University of Michigan, Ann Arbor

Christopher K. R. T. Jones
Brown University

William L. Kath
Northwestern University

Yakov Pesin
Pennsylvania State University

Vered Rom-Kedar
Weizmann Institute of Science, Israel

Michael Tabor
University of Arizona

A Message from the Conference Chairs...

Dear Colleagues:

Welcome to Snowbird for the Fourth SIAM Conference on Applications of Dynamica Systems.

This highly interdisciplinary meeting brings together a diverse group of mathematicians scientists, and engineers, all working on dynamical systems and their applications. Th themes were chosen to highlight those areas in which dynamical systems has recently mad exciting progress and to provide a forum for discussion of future directions.

The response to our Call for Papers was extraordinary. As a result, the program is packed ful of fascinating sessions. Besides the 11 Invited Presentations, we have 51 Minisymposia, 3' sessions of Contributed Papers, and 2 Poster Sessions. Although it was combinatoriall impossible, we have tried hard to avoid conflicts.

We hope you'll find this conference, and your visit to Snowbird, to be stimulating educational, and fun.

Mary Silber and Steve Strogatz
Co-Chairs, Organizing Committee

Audiovisual Notice

Two standard overhead projectors and two screens will be provided in every meeting ro Speakers with special audiovisual equipment needs should inform SIAM of their spec requirements by April 25, 1997. If we do not hear from speakers by that date, it will be underst that a standard overhead projector is all that is needed.

If a speaker sends a request for special audiovisual equipment and decides not to use requested equipment after it has been installed, the speaker will be responsible for paying rental fee.

Some examples of special audiovisual equipment and rental fees are

LCD Panel	$250	26" Data Monitor	$2
35mm Slide Projector	$38	Shure Mixer	$
Video Projector	$500	IBM PC Computer	$2
1/2" VHS VCR	55	Xenon 35mm Projector	$2

Important Notice to all Meeting Participants

Times allowed for each presentation, including questions and answers:

CP = Contributed Presentations (20 minutes)

IP = Invited Plenary Presentations (60 minutes)

MS = Minisymposium (30 minutes)

There are two Poster Sessions. Poster I will take place on Tuesday evening from 7:30 PM-9 PM. Poster II will take place at the same time on Wednesday evening. There will be recepti during these sessions. Poster presenters are asked to post their materials at 6:30 PM on eit day that they are scheduled. By 9:30 PM on Tuesday or Wednesday, all posted materi should be removed from the poster boards. Any materials left on the board after that ti will be removed and discarded. SIAM cannot be responsible for any discarded pos displays that are left at the end of the session.

For more information about Poster presentations, please refer to "Guidelines for Meet Participants" at *http://www.siam.org/meetings/guidhome.htm.*

For papers will multiple authors, the speaker is shown in italics if known at press time.

The conference organizers expect every speaker of a scheduled presentation to register and att the conference. If it becomes necessary for a speaker to cancel the presentation, the speake expected to find an alternate presenter, or one of the speaker's co-authors should give presentation. The speaker should inform the SIAM conference department of any change to l her scheduled presentation.

A "no-show" or canceled presentation can cause serious inconvenience to the attendees a conference organizers.

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REF: Grant #N00014-97-1-0404

Gentlemen:

Enclosed is one (1) copy of the Final Program and Abstract book for the SIAM Conference on Dynamical Systems held in Snowbird, UT on May 19-12, 1997. No proceedings will be published for this conference.

Sincerely,

A Robert Bellace

A. Robert Bellace
Director, Finance & Administration

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PROGRAM OVERVIEW

Following are subject classifications for the sessions. The codes in parentheses designate session type and number. The session types are contributed presentations (CP), invited presentations (IP), minisymposia (MS), and poster presentations. The poster presentations are in two sessions — Poster I and Poster II, Tuesday and Wednesday evenings, respectively.

Principal Themes

Dynamics in Undergraduate Education
Teaching Differential Equations Dynamically (MS24)
Teaching Dynamical Systems to Undergraduates (IP3)
Teaching Dynamics (CP17)

Hamiltonian Systems and Transport
Hamiltonian Systems (CP8)
Integrable Systems Methods for Curve Evolution (MS22)
Slow Evolution in Conservative Systems (MS17)
Transport in Hamiltonian Systems (MS36)

Mathematical Biology
Biological Microswimming (MS28)
Biology (CP30)
Biomolecular Motors (IP7)
Bursting and Biochemical Oscillations (CP23)
Continuum Models of Biological Macromolecules (MS32)
Dynamical and Statistical Modeling of Biological Systems (MS42)
Dynamics of Cortical Neural Networks - Parts I and II (MS17), (MS23)
Dynamics of Curves and Filaments (MS25)
Mathematics and Medicine: From the Laboratory to the Clinic (MS10)
Molecular Motors (MS35)
Neural and Excitable Systems (CP18), (CP20)

Noise in Dynamical Systems
New Results for Stochastic PDEs (MS12)
Noise and Heteroclinic Phenomena (MS48)
Nonlinear Dynamics of Large Fluctuations (MS19)
Processing Signals from Noisy Chaotic Systems (MS8)
Random Dynamical Systems (MS26)
Stochastic Resonance (CP25)
Stochastic Resonance in Medicine and Biology (MS3)
Stochastic Resonance in Sensory Biology (IP5)

Patterns and Spatio-Temporal Chaos
Complex Ginzburg-Landau Equations as Perturbations of Nonlinear Schrödinger Equations (IP11)
Experiments on Spatio-Temporal Chaos (MS1)
Intricate Interfaces and Modulated Membranes - Their Geometry and Nonlinear Dynamics (IP2)
Karhunen-Loeve Methods (CP31)
Model Reduction, Analysis, and Control of Spatio-Temporal Dynamics Using KL Methods (MS31)
Nonlinear Dynamics and Pattern Formation in Combustion (MS50)
Pattern Formation and Singular Perturbations (MS18)
Reaction-Diffusion Equations (CP26)
Spatio-Temporal Chaos (CP27)
Spatio-Temporal Chaos: Characterization and Control (MS6)
Spiral-Wave Domains and Filaments: Experiments, Numerics, Theory (MS11)
Universal Spatio-Temporal Chaos in Large Assemblies of Simple Dynamical Units (IP10)
Waves and Ginzburg-Landau Equations (CP24)

Synchronization
Applications of Synchronized Chaos and Hyperchaos (MS38)
Communicating with Chaos (MS5)
Nonlinear Oscillators (MS9)
Phase Dynamics and Synchronization in Chaotic Systems (MS16)
Riddling in Chaotic Systems (MS51)
Synchronization I and II (CP9), (CP21)

Applications in:

Aerospace Engineering
Nonlinear Phenomena in Aeroengine Dynamics and Control (MS4)

Condensed Matter Physics
Applications in Physics (CP13)
Dynamical Systems Theory and Non-equilibrium Statistical Mechanics (MS44)
Josephson Junction Arrays: Progress and Puzzles (MS21)

Control
Control and Shadowing (MS47)
Controlling Chaos (CP19)
Engineering and Control (CP37)
Nonlinear Control of Lagrangian Systems (IP9)
Periodic Orbits in Chaotic Systems (MS40)
Unstable Periodic Orbits (CP5)

Fluids
Chaotic Advection, Turbulence, and Transport (CP32), (CP35)
Convection and Hexagonal Patterns (CP14)
Diffusion and Turbulence on Water Surfaces (MS15)
Fluids (CP16), (CP29)
Nonlinear Waves (CP11)
Scaling Exponents in Turbulence (IP4)

Lasers and Optical Fibers
Dynamics of Laser Arrays: Coherence, Chaos, and Control (MS45)
Fundamental Nonlinear Dynamics of Diode Lasers (MS37)
Lasers (CP1)
Nonlinear Optics and Solitons (CP4), (CP7)
Periodically and Randomly Driven Dynamics in Nonlinear Optical Fibers (MS33)

Manufacturing
Bucket Brigade Production Lines (IP6)

Mechanics
Applied Mechanics (CP3)

Oceanography
Dynamical System Methods for Oceanic and Atmospheric Flows - Parts I and II (MS2) and (MS7)
Interplay of Fluid Dynamics and Biology of Plankton Population Models (MS13)
Lagrangian Transport in Mesoscale Ocean Structures (IP1)
Low-Frequency Variability in the Double-Gyre Circulation (MS30)

Quantum Chaos
New Directions in Quantum Chaos (MS43)
Small Electronics and Quantum Chaos (IP8)

Mathematical Methods
Applications of the Geometric Phase (MS41)
Attractors, Fractals, and Dimensions (CP10)
Bifurcation and Symmetry (CP33)
Bifurcation Theory and Systems of Nonlinear Conservation Laws (MS29)
Computing Invariant Manifolds (MS20)
Energy Transfer in Nonlinear Partial Differential Equations (MS46)
Invariant Measures and Ergodicity (CP12)
Maps (CP6)
Melnikov Theory (CP22)
Melnikov Methods for Partial Differential Equations (MS49)
Numerical Methods (CP28)
Partial Differential Equations (CP36)
Perturbation Methods and ODEs (CP2)
Singular Parturbations (CP15)
Spatially Discrete Dynamical Systems — Theory and Applications (MS39)
Time Series and Signal Processing (CP34)
Topology in Dynamics (MS34)
Ulam's Conjecture and the Approximation of Invariant Measures (MS14)

PROGRAM-AT-A-GLANCE

Saturday, May 17

Evening

6:00 PM-8:00 PM
Registration
Ballroom Lobby - Level B

6:00 PM-8:00 PM
Welcoming Reception
Golden Cliff Room - Level B

Sunday, May 18

Morning

7:30 AM-4:00 PM
Registration
Ballroom Lobby - Level B

8:15 AM
Welcome Remarks and Announcements

Mary Silber and Steven Strogatz

8:30 AM-9:30 AM

IP1 Lagrangian Transport in Mesoscale Ocean Structures
Christopher K. R. T. Jones, Brown University

Chair: Roberto Camassa, Los Alamos National Laboratory

Ballroom I, II, III - Level B

9:30 AM-10:00 AM
Coffee

Ballroom Lobby - Level B and Mezzanine Lobby - Level C

10:00 AM-12:00 PM
Concurrent Sessions

MS1 Experiments on Spatio-Temporal Chaos
Organizer: Eberhard Bodenschatz, Cornell University

Ballroom I - Level B

MS2 Dynamical System Methods for Oceanic and Atmospheric Flows (Part I of II)
Organizer: Roberto Camassa, Los Alamos National Laboratory

Ballroom II - Level B

MS3 Stochastic Resonance in Medicine and Biology
Organizer: James J. Collins, Boston University

Ballroom III - Level B

MS4 Nonlinear Phenomena in Aeroengine Dynamics and Control
(This session has been cancelled)

Organizer: Mark R. Myers, United Technologies Research Center

Magpie A & B - Level B

MS5 Communicating with Chaos
Organizer: Epaminondas Rosa, Jr., University of Maryland, College Park

Wasatch A & B - Level C

CP1 Lasers
Chair: Peter A. Braza, University of North Florida

Maybird - Level C

CP2 Perturbation Methods and ODEs
Chair: Ferdinand Verhulst, University of Utrecht, The Netherlands

Superior B - Level C

CP3 Applied Mechanics
Chair: Marian Wiercigroch, University of Aberdeen, Kings College, United Kingdom

Superior A - Level C

Afternoon

12:00 PM-1:30 PM
Lunch

1:30 PM-2:30 PM

IP2 Intricate Interfaces and Modulated Membranes – Their Geometry and Nonlinear Dynamics
Raymond E. Goldstein, University of Arizona

Chair: Michael Tabor, University of Arizona

Ballroom I, II, III - Level B

2:30 PM-3:00 PM
Coffee

Ballroom Lobby - Level B and Mezzanine Lobby - Level C

3:00 PM-5:00 PM
Concurrent Sessions

MS6 Spatio-Temporal Chaos: Characterization and Control
Organizer: Hermann Riecke, Northwestern University

Ballroom I - Level B

MS7 Dynamical System Methods for Oceanic and Atmospheric Flows (Part II of II)
Organizer: Roberto Camassa, Los Alamos National Laboratory

Ballroom II - Level B

MS8 Processing Signals from Noisy Chaotic Systems
Organizers: Mark Muldoon, University of Manchester Institute of Science and Technology, United Kingdom; and Holger Kantz, Max Planck Institute for Physics of Complex Systems, Germany

Magpie A & B - Level B

MS9 Nonlinear Oscillators
Organizer: Richard H. Rand, Cornell University

Wasatch A & B - Level C

MS10 Mathematics and Medicine: From the Laboratory to the Clinic
Organizer: Michael C. Mackey, McGill University, Canada

Ballroom III - Level B

CP4 Nonlinear Optics and Solitons I
Chair: Anne Niculae, Northwestern University

Superior B - Level C

CP5 Unstable Periodic Orbits
Chair: Steven J. Schiff, Children's National Medical Center

Maybird - Level C

CP6 Maps
Chair: Colin Sparrow, University of Cambridge, United Kingdom

Superior A - Level C

Evening

5:00 PM-7:00 PM
Dinner (attendees will be on their own)

7:00 PM-9:00 PM
Concurrent Sessions

MS11 Spiral-Wave Domains and Filaments: Experiments, Numerics, Theory
Organizer: Gregory Huber, University of Chicago

Ballroom I - Level B

MS12 New Results for Stochastic PDES
Organizer: Charles R. Doering, University of Michigan, Ann Arbor

Ballroom II - Level B

MS13 Interplay of Fluid Dynamics and Biology of Plankton Population Models
Organizer: John Brindley, University of Leeds, United Kingdom

Ballroom III - Level B

MS14 Ulam's Conjecture and the Approximation of Invariant Measures
(This session will run until 9:30 PM)

Organizer: Fern Y. Hunt, National Institute of Standards and Technology

Superior A - Level C

CP7 Nonlinear Optics and Solitons II
Chair: William L. Kath, Northwestern University

Magpie A & B - Level B

CP8 Hamiltonian Systems
Chair: M. C. Depassier, Universidad Catolica de Chile, Chile

Superior B - Level C

CP9 Synchronization I
Chair: Reggie Brown, College of William & Mary

Wasatch A & B - Level C

CP10 Attractors, Fractals, and Dimensions
Chair: Brian Hunt, University of Maryland, College Park

Maybird - Level C

NOTE: Please refer to the Important Notice to all Meeting Participants.

PROGRAM-AT-A-GLANCE

Monday, May 19

Morning

7:30 AM-4:00 PM
Registration
Ballroom Lobby - Level B

8:30 AM-9:30 AM
IP3 Teaching Dynamical Systems to Undergraduates
Robert L. Devaney, Boston University
Chair: Robert Borrelli, Harvey Mudd College
Ballroom I, II, III - Level B

9:30 AM-10:00 AM
Coffee
Ballroom Lobby - Level B and Mezzanine Lobby - Level C

10:00 AM-12:00 PM
Concurrent Sessions

MS15 Diffusion and Turbulence on Water Surfaces
Organizer: Preben Alstrom, Niels Bohr Institute, Denmark
Magpie A & B - Level B

MS16 Phase Dynamics and Synchronization in Chaotic Systems
Organizer: Jürgen Kurths, Universität Potsdam, Germany
Ballroom I - Level B

MS17 Dynamics of Cortical Neural Networks (Part I of II)
Organizers: Xiao-Jing Wang, Brandeis University; David Terman, Ohio State University, Columbus; and John Rinzel, National Institutes of Health
Ballroom II - Level B

MS18 Pattern Formation and Singular Perturbations
Organizers: Arjen Doelman, University of Utrecht, The Netherlands; Tasso Kaper, Boston University; and Todd Kapitula, University of New Mexico, Albuquerque
Ballroom III - Level B

MS19 Nonlinear Dynamics of Large Fluctuations
Organizer: Mark I. Dykman, Michigan State University
Wasatch A & B - Level C

CP11 Nonlinear Waves
Chair: Manfred F. Goz, Princeton University
Maybird - Level C

CP12 Invariant Measures and Ergodicity
Chair: Yuri Latushkin, University of Missouri, Columbia
Superior A - Level C

CP13 Applications in Physics
Chair: Adam S. Landsberg, Haverford College
Superior B - Level C

Afternoon

12:00 PM-1:30 PM
Lunch

1:30 PM-2:30 PM
IP4 Scaling Exponents in Turbulence
Peter S. Constantin, University of Chicago
Chair: Peter Bates, Brigham Young University
Ballroom I, II, III - Level B

2:30 PM-3:30 PM
IP5 Stochastic Resonance in Sensory Biology
Frank Moss, University of Missouri, St. Louis
Chair: John Rinzel, National Institutes of Health
Ballroom I, II, III - Level B

3:30 PM-4:00 PM
Coffee
Ballroom Lobby - Level B and Mezzanine Lobby - Level C

4:00 PM-6:00 PM
Concurrent Sessions

MS20 Computing Invariant Manifolds
Organizer: John Guckenheimer, Cornell University
Magpie A & B - Level B

MS21 Josephson Junction Arrays: Progress and Puzzles
Organizer: Kurt A. Wiesenfeld, Georgia Institute of Technology
Ballroom I - Level B

MS22 Integrable Systems Methods for Curve Evolution
Organizers: Annalisa Calini, University of Charleston; and Thomas Ivey, Case Western Reserve University
Wasatch A & B - Level C

MS23 Dynamics of Cortical Neural Networks (Part II of II)
Organizers: Xiao-Jing Wang, Brandeis University; David Terman, Ohio State University, Columbus; and John Rinzel, National Institutes of Health
Ballroom II - Level B

MS24 Teaching Differential Equations Dynamically
Organizer: Beverly H. West, Harvey Mudd College and Cornell University
Ballroom III - Level B

CP14 Convection and Hexagonal Patterns
Chair: Anne C. Skeldon, City University, United Kingdom
Maybird - Level C

CP15 Pattern Formation and Singular Perturbations II
Chair: Tasso Kaper, Boston University
Superior B - Level C

CP16 Fluids I
Chair: Brian F. Farrell, Harvard University
Superior A - Level C

Evening

6:00 PM-7:00 PM
Business Meeting
SIAM Activity Group on Dynamical Systems
Golden Cliff Room - Level B

Tuesday, May 20

Morning

7:30 AM-4:00 PM
Registration
Ballroom Lobby - Level B

8:30 AM-9:30 AM
IP6 Bucket Brigade Production Lines
Leonid A. Bunimovich, Georgia Institute of Technology
Chair: Kurt Wiesenfeld, Georgia Institute of Technology
Ballroom I, II, III - Level B

9:30 AM-10:00 AM
Coffee
Ballroom Lobby - Level B and Mezzanine Lobby - Level C

10:00 AM-12:00 PM
Concurrent Sessions

MS25 Dynamics of Curves and Filaments
Organizer: Isaac Klapper, Montana State University
Ballroom I - Level B

MS26 Random Dynamical Systems
(This session will run until 12:30 PM)
Organizer: N. Sri Namachchivaya, University of Illinois, Urbana
Ballroom II - Level B

MS27 Slow Evolution in Conservative Systems
Organizer: Norman R. Lebovitz, University of Chicago
Wasatch A & B - Level C

MS28 Biological Microswimming
Organizers: Richard W. Montgomery, University of California, Santa Cruz; and Jair Koiller, Laboratorio Nacional de Computacao Cientifica, Brazil
Ballroom III - Level B

MS29 Bifurcation Theory and Systems of Nonlinear Conservation Laws
Organizer: Stephen Schecter, North Carolina State University
Maybird - Level C

PROGRAM-AT-A-GLANCE

Tuesday, May 20

CP17 Teaching Dynamics
Chair: James A. Walsh, Oberlin College

Superior A- Level C

CP18 Neural and Excitable Systems I
Chair: Tomas Gedeon, Montana State University

Superior B - Level C

CP19 Controlling Chaos
Chair: Elbert E. N. Macau, University of Maryland, College Park

Magpie A & B - Level B

Afternoon

12:00 PM-1:30 PM
Lunch

1:30 PM-2:30 PM

IP7 Biomolecular Motors
Charles S. Peskin, Courant Institute of Mathematical Sciences, New York University

Chair: Charles R. Doering, University of Michigan, Ann Arbor

Ballroom I, II, III - Level B

2:30 PM-3:00 PM
Coffee

Ballroom Lobby - Level B and Mezzanine Lobby - Level C

3:00 PM-5:00 PM
Concurrent Sessions

MS30 Low-Frequency Variability in the Double-Gyre Circulation
Organizers: Balu T. Nadiga and Darryl D. Holm, Los Alamos National Laboratory

Magpie A & B - Level B

MS31 Model Reduction, Analysis, and Control of Spatio-Temporal Dynamics Using KL Methods
Organizer: Ira B. Schwartz, U.S. Naval Research Laboratory

Ballroom I - Level B

MS32 Continuum Models of Biological Macromolecules
Organizer: John H. Maddocks, University of Maryland, College Park

Wasatch A & B - Level C

MS33 Periodically and Randomly Driven Dynamics in Nonlinear Optical Fibers
Organizers: J. Nathan Kutz, Princeton University; and William L. Kath, Northwestern University

Ballroom II - Level B

MS34 Topology in Dynamics
Organizer: James Yorke, University of Maryland, College Park

Ballroom III - Level B

CP20 Neural and Excitable Systems II
Chair: Amitabha Bose, New Jersey Institute of Technology

Superior B - Level C

CP21 Synchronization II
Chair: Peter Smereka, University of Michigan, Ann Arbor

Maybird - Level C

CP22 Melnikov Theory
Chair: Timothy Whalen, National Institute of Standards and Technology

Superior A - Level C

Evening

5:30 PM-7:00 PM
Dinner (attendees are on their own)

6:30 PM-7:30 PM Poster setup

Ballroom I, II, III - Level B

7:30 PM-9:30 PM
Poster Session

Dessert and Coffee will be served

Poster Session I
Ballroom I, II, III - Level B

Wednesday, May 21

Morning

7:30 AM-4:00 PM
Registration

Ballroom Lobby - Level B

8:30 AM-9:30 AM

IP8 Small Electronics and Quantum Chaos
Charles M. Marcus, Stanford University

Chair: Boris L. Altshuler, NEC Research, Inc.

Ballroom I, II, III - Level B

9:30 AM-10:00 AM
Coffee

Ballroom Lobby - Level B and Mezzanine Lobby - Level C

10:00 AM-12:00 PM
Concurrent Sessions

MS35 Molecular Motors
Organizer: George F. Oster, University of California, Berkeley

Magpie A & B - Level B

MS36 Transport in Hamiltonian Systems
Organizer: Vered Rom-Kedar, Weizmann Institute of Science, Israel

Ballroom I - Level B

MS37 Fundamental Nonlinear Dynamics of Diode Lasers
Organizer: Bernd Krauskopf, Vrije Universiteit, The Netherlands

Ballroom II - Level B

MS38 Applications of Synchronized Chaos and Hyperchaos
Organizer: Louis M. Pecora, Naval Research Laboratory

Ballroom III - Level B

MS39 Spatially Discrete Dynamical Systems — Theory and Applications
Organizers: John Mallet-Paret, Brown University; and Shui-Nee Chow, Georgia Institute of Technology

Wasatch A & B - Level B

CP23 Bursting and Biochemical Oscillations
Chair: William R. Derrick, University of Montana

Superior A - Level C

CP24 Waves and Ginzburg-Landau Equations
Chair: Rebecca Hoyle, University of Cambridge, United Kingdom

Superior B - Level C

CP25 Stochastic Resonance
Chair: Bruce J. Gluckman, Naval Surface Warfare Center and the Children's Research Institute of George Washington University

Maybird - Level C

Afternoon

12:00 PM-1:30 PM
Lunch

1:30 PM-2:30 PM

IP9 Nonlinear Control of Lagrangian Systems
Richard M. Murray, California Institute of Technology

Chair: Jerrold E. Marsden, California Institute of Technology

Ballroom I, II, III - Level B

2:30 PM-3:00 PM
Coffee

Ballroom Lobby - Level B and Mezzanine Lobby - Level C

3:00 PM-5:00 PM
Concurrent Sessions

MS40 Periodic Orbits in Chaotic Systems
Organizers: Ernest Barreto and Edward Ott, University of Maryland, College Park

Ballroom I - Level B

MS41 Applications of the Geometric Phase
Organizers: Jerrold E. Marsden, California Institute of Technology; and Paul K. Newton, University of Southern California

Ballroom II - Level B

MS42 Dynamical and Statistical Modeling of Biological Systems
Organizer: Yuhai Tu, IBM T. J. Watson Research Center

Ballroom III - Level B

PROGRAM-AT-A-GLANCE

Wednesday, May 21

MS43 Quantum Chaos and Mesoscopic Physics
Organizer: Charles M. Marcus, Stanford University

Magpie A & B- Level B

CP26 Reaction-Diffusion Equations
Chair: Jack Dockery, Montana State University

Wasatch A & B - Level C

CP27 Spatio-Temporal Chaos
Chair: David Peak, Utah State University

Maybird - Level C

CP28 Numerical Methods
Chair: Robert L. Warnock, Stanford University

Superior A - Level C

CP29 Fluids II
Chair: Robert Ghrist, University of Texas, Austin

Superior B- Level C

Evening

5:30 PM-7:00 PM
Dinner (attendees are on their own)

6:30 PM-7:30 PM
Poster setup starts

Ballroom I, II, III - Level B

7:30 PM-9:30 PM
Poster Session opens

Dessert and Coffee will be served

Poster Session II
Ballroom I, II, III - Level B

Thursday, May 22

Morning

7:30 AM-10:00 AM
Registration

Ballroom Lobby - Level B

8:30 AM-9:30 AM

IP10 Universal Spatio-Temporal Chaos in Large Assemblies of Simple Dynamical Units
Yoshiki Kuramoto, Kyoto University, Japan

Chair: Rajarshi Roy, Georgia Institute of Technology

Ballroom I, II, III - Level B

9:30 AM-10:00 AM
Coffee

Ballroom Lobby - Level B and Mezzanine Lobby - Level C

10:00 AM-12:00 PM
Concurrent Sessions

MS44 Dynamical Systems Theory and Nonequilibrium Statistical Mechanics
Organizer: Robert Dorfman, University of Maryland, College Park

Ballroom I - Level B

MS45 Dynamics of Laser Arrays: Coherence, Chaos and Control
Organizer: Rajarshi Roy, Georgia Institute of Technology

Ballroom II - Level B

MS46 Energy Transfer in Nonlinear Partial Differential Equations
Organizer: Michael I. Weinstein, University of Michigan, Ann Arbor

Magpie A & B - Level B

MS47 Control and Shadowing
Organizer: Eric J. Kostelich, Arizona State University

Ballroom III - Level B

CP30 Biology
Chair: Sharon R. Lubkin, University of Washington

Superior B - Level C

CP31 Karhunen-Loeve Methods
Chair: Thomas W. Carr, Southern Methodist University

Superior A - Level C

CP32 Chaotic Advection, Turbulence, and Transport I
Chair: Patrick D. Miller, Brown University

Wasatch A & B - Level C

CP33 Bifurcation and Symmetry
Chair: Sue Ann Campbell, University of Waterloo, Canada

Maybird - Level C

Afternoon

12:00 PM-1:30 PM
Lunch

1:30 PM-2:30 PM

IP11 Complex Ginzburg-Landau Equations as Perturbations of Nonlinear Schrödinger Equations
C. David Levermore, University of Arizona

Chair: Vered Rom-Kedar, Weizmann Institute of Science, Israel

Ballroom I, II, III - Level B

2:30 PM-3:00 PM
Coffee

Ballroom Lobby - Level B and Mezzanine Lobby - Level C

3:00 PM-5:00 PM
Concurrent Sessions

MS48 Noise and Heteroclinic Phenomena
Organizers: Vivien Kirk, University of Auckland, New Zealand; and Emily Stone,

Utah State University

Ballroom I - Level B

MS49 Melnikov Methods for Partial Differential Equations
Organizers: Constance M. Schober, Old Dominion University; and Gregor Kovacic,

Rensselaer Polytechnic Institute

Ballroom II - Level B

MS50 Nonlinear Dynamics and Pattern Formation in Combustion
Organizer: Vladimir A. Volpert, Northwestern University

Magpie A & B - Level B

MS51 Riddling in Chaotic Systems
Organizer: Ying-Cheng Lai, University of Kansas

Ballroom III - Level B

CP34 Time Series and Signal Processing
Chair: Michael E. Davies, University College London, United Kingdom

Maybird - Level C

CP35 Chaotic Advection, Turbulence, and Transport II
Chair: Diego del Castillo-Negrete, University of California, San Diego

Wasatch A & B- Level C

CP36 Partial Differential Equations
Chair: Jinqiao Duan, Clemson University

Superior B - Level C

CP37 Engineering and Control
Chair: Hans True, Technical University of Denmark, Denmark

Superior A - Level C

5:20 Conference adjourns

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8:30 AM-9:30AM

Chair: Roberto Camassa, Los Alamos National Laboratory
Ballroom I, II, III - Level B

IPI

Lagrangian Transport in Mesoscale Ocean Structures

Much activity in the ocean is mediated by mesoscale structures, such as meandering jets and vortex rings. How these structures share fluid, and thus fluid properties, with the ambient ocean, and how they transport fluid between different parts of their own internal structure, is crucial in estimating and understanding their impact on ocean properties at all scales. Quantifying such transport is a problem in dynamical systems, but one that poses many new challenges because simple analytic models are far too crude to offer us any real understanding. Recent progress on the development of techniques for transport studies within realistic numerical models will be discussed. Comparisons will be given between the extent of Lagrangian transport predicted by these models for structures such as the Gulf Stream and transport across the Gulf Stream by other mechanisms, such as ring detachment. Recent work on considerations of viscosity-induced transport suggests some surprising conclusions as to the dominant mode of transport out of meandering jets. This latter work involves a Melinkov calculation on the perturbed velocity field, about which little is known other than it satisfies a certain PDE.

Christopher K. R. T. Jones
Division of Applied Mathematics
Brown University

10:00 AM-12:00 PM

Ballroom I - Level B

MS1

Experiments on Spatio-Temporal Chaos

The minisymposium brings together four experimentalists working on spatio-temporal disorder/chaos (STC) in vastly different systems. This minisymposium will address STC in chemical oscillations, in the aggregation of slime mold amoebae, in optical resonators, and in thermal convection. Spatio-temporal chaos appears to be a generic state occurring in dynamical systems when the system size (aspect-ratio) is increased and spatial degrees of freedom become important. To date, no clear understanding of spatio temporal chaos has emerged. This minisymposium is set up to attract the attention of the "dynamical" community to the problem of spatio-temporal chaos. It will also show that we have well-defined and controllable experimental systems that allow quantitative comparison with theories.

Organizer: Eberhard Bodenschatz
Cornell University

10:00 Transitions from Spiral Waves to Chemical Turbulence in a Reaction-Diffusion System
Qi Ouyang, NEC Research Institute, Inc.

10:30 Competition Between Spiral Waves and Targets in Dictyostelium Discoideum
Raymond E. Goldstein, University of Arizona

11:00 A Primary Bifurcation to Spatio-Temporal Chaos
Michael Dennin, University of California, Irvine

11:30 Spatio-Temporal Chaos in Rayleigh-Benard Convection
Eberhard Bodenschatz, Organizer

10:00 AM-12:00 PM

Ballroom II - Level B

MS2

Dynamical System Methods for Oceanic and Atmospheric Flows (Part I of II)

Numerical simulations of atmospheric and oceanic flows are reaching a stage where quantitative comparisons with real data are possible. While this progress constitutes a striking confirmation of the validity of the basic models, like the Primitive Equations, sometimes it falls short of enhancing our understanding of the basic mechanisms at play for certain phenomena. To gain some insight it is still useful to study simpler models that target a specific mechanism expected to be important. It is in this context that dynamical systems methods can be effective. The minisymposium's aim is to provide several examples in this direction.

Organizer: Roberto Camassa
Los Alamos National Laboratory

10:00 Dynamical Systems Theory and Dynamical Oceanography
Roger M. Samelson, Woods Hole Oceanographic Institution

10:30 Advection Induced by the Breaking of Vorticity Conservation via Viscous Dissipation
Sanjeeva Balasuriya, University of Peradeniya, Sri Lanka; Christopher K. R. T. Jones and Björn Sandstede, Brown University

11:00 Mathematical Problems in the Theory of Shallow Water
Marcel Oliver, University of California, Irvine

11:30 Inverse Scattering Analysis of Internal Waves in the Andaman Sea
A. R. Osborne, University of Torino, Italy

10:00 AM-12:00 PM

Ballroom III - Level B

MS3

Stochastic Resonance in Medicine and Biology

Stochastic resonance (SR) is a phenomenon wherein the response of a nonlinear system to a weak input signal is optimized by the presence of a particular level of noise. SR has been examined theoretically and experimentally in a wide variety of systems, including biological systems. This minisymposium will focus on recent SR studies that deal with neurophysiological sensory systems, including the theoretical and experimental techniques that are used to characterize SR in sensory neurons. Possible physiological and clinical applications of SR (e.g., noise-enhanced sensory function in humans) will also be addressed, along with the biophysical and bioengineering challenges surrounding these applications.

Organizer: James J. Collins
Boston University

10:00 Noise, Hair Cells, and the Leopard Frog
Kurt Wiesenfeld and Peter Jung, Georgia Institute of Technology; and Fernan Jaramillo, Emory University

10:30 Noise-Enhanced Sensory Function
James J. Collins, Organizer

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11:00 Stochastic Resonance in Human Muscle Spindles-A Potential Mechanism for Fusimotor Gain Control
Paul J. Cordo, R. S. Dow Neurological Sciences Institute; Sabine M. P. Verschueren, Catholic University of Leuven, Belgium; J. Timothy Inglis, University of British Columbia, Canada; Frank Moss, University of Missouri, St. Louis; Daniel M. Merfeld, R. S. Dow Neurological Sciences Institute; and James J. Collins, Organizer

11:30 Augmentation of Sensory Nerve Action Potentials During Muscle Contraction
Faye Y. Chiou-Tan, Kevin N. Magee, Stephen Tuel, Lawrence Robinson, Thomas Krouskop, Maureen R. Nelson, and Frank Moss, Baylor College of Medicine

10:00 AM-12:00 PM

This session has been cancelled.

MS4

Nonlinear Phenomena in Aeroengine Dynamics and Control

Organizer: Mark R. Myers
United Technologies Research Center

10:00 AM-12:00 PM

Wasatch A & B - Level C

MS5

Communicating with Chaos

The realization that chaos can be controlled by small perturbations leads to the idea that chaotic systems can be used to produce a signal bearing desired information. In fact, it has been demonstrated experimentally that the symbolic dynamics of a chaotic attractor can be made to follow a prescribed symbol sequence, so any desired message can be encoded and transmitted. In this minisymposium the basic ideas of chaos in communication and the experiments that demonstrate their implementation will be presented. Recent developments in higher dimensional encoding and filtering of in-band noise will also be introduced.

Organizer: Epaminondas Rosa, Jr.
University of Maryland, College Park

10:00 Noise Filtering in Communication with Chaos
Epaminondas Rosa, Jr., Organizer

10:30 Experimental Control of Chaos for Communication
Scott Hayes, U.S. Army Research Laboratory

11:00 Higher Dimensional Symbolic Encoding
Ying-Chen Lai, University of Kansas

11:30 Encoding Information in Chemical Chaos
Erik M. Bollt, United States Military Academy

10:00 AM-12:00 PM

Chair: Peter A. Braza, University of North Florida
Maybird - Level C

CP1

Lasers

10:00 Phase Jumps of pi in a Laser with a Periodically Forced Injected Signal
Peter A. Braza, University of North Florida

10:20 Homoclinic Orbits for the Second Harmonic Generation of Light in an Optical Cavity
Alejandro B. Aceves, University of New Mexico, Albuquerque; Darryl D. Holm, Los Alamos National Laboratory; Gregor Kovacic and *Ilya Timofeyev*, Rensselaer Polytechnic Institute

10:40 Synchronized Patterns in Coupled Lasers
Gerhard Dangelmayr, Colorado State University; and Michael Wegelin, University of Tubingen, Germany

11:00 Spatio-Temporal Dynamics of Broad-Area Semiconductor Lasers with Optical Feedback
George R. Gray and Ming-Wei Pan, University of Utah; and David H. DeTienne, Nichols Corporation, Salt Lake City

11:20 Bifurcation Diagram of Two Lasers with Injected Field
A. I. Khibnik, Cornell University; Y. Braiman, Emory University; T. A. B. Kennedy and Kurt Wiesenfeld, Georgia Institute of Technology

11:40 Nonlinear Dynamics of Semiconductor Laser Arrays
Luis F. Romero, Emilio L. Zapata, and J. I. Ramos, University of Malaga, Spain

10:00 AM-12:00 PM

Chair: Ferdinand Verhulst, University of Utrecht, The Netherlands
Superior B - Level C

CP2

Perturbation Methods and ODEs

10:00 Hamiltonian G-space Normal Forms as a Geometric Framework for Perturbation Theory
Anthony Blaom, California Institute of Technology

10:20 Evolution Towards Symmetry
Ferdinand Verhulst, University of Utrecht, The Netherlands

10:40 The Moving Singularities of the Perturbation Expansion of the Classical Kepler Problem
Mohammad Tajdari, University of New England

11:00 Necessary and Sufficient Conditions for Finite-Time Blow-Up in ODE's
Craig Hyde and Alain Goriely, University of Arizona

11:20 Simple Periodic Orbits in 1-1-1 Resonance: Cubic and Quartic Potentials
S. Ferrer, Universidad de Zaragoza, Spain; M. Lara, Real Instituto y Observatorio de la Armada, Spain; *J. Palacian*, Universidad Publica de Navarra, Spain; J. F. San Juan, Universidad de La Rioja, Spain; and P. Yanguas, Universidad Publica de Navarra, Spain

11:40 Fast Resonance Shifting as a Mechanism of Instability in Dynamics Illustrated by Comets
Edward Belbruno, The Geometry Center

10:00 AM-12:00 PM

Chair: Marian Wiercigroch, University of Aberdeen, Kings College, United Kingdom
Superior A - Level C

CP3

Applied Mechanics

10:00 Forced Oscillations of a Discretely Supported Nonlinear String Using Nonsmooth Transformations
Gary Salenger and *Alexander F. Vakakis*, University of Illinois, Urbana

10:20 Homoclinic Orbits and Localized Buckling of Cylindrical Shells
Gabriel J. Lord and Alan R. Champneys, University of Bristol, United Kingdom; and Giles W. Hunt, University of Bath, United Kingdom

10:40 Stochastic Effect on Chaotic Dynamics of Cutting Process
Marian Wiercigroch, University of Aberdeen, Kings College, United Kingdom; and Alexander H-D. Cheng, University of Delaware

11:00 Dynamical Friction Modeling
Harry Dankowicz, Royal Institute of Technology, Sweden

11:20 Critical Behaviour in the Torsional Buckling of Anisotropic Rods
G. H. M. van der Heijden and J. M. T. Thompson, University College London, United Kingdom

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11:40 Graph Theoretic Implications for Piecewise Linear Systems of Arbitrary Dimension
John Hogan and Martin Homer, University of Bristol, United Kingdom

1:30 PM-2:30 PM

Chair: Michael Tabor, University of Arizona
Ballroom I, II, III - Level B

IP2

Intricate Interfaces and Modulated Membranes - Their Geometry and Nonlinear Dynamics

Many problems in pattern formation involve the conformations and dynamics of filaments, interfaces, and surfaces. Theoretical descriptions of phenomena such as the fingering of flux domains in superconductors, chemical front motion in gel reactors, and propagating shape transformations in lipid vesicles all share common structures of global conservation laws, nontrivial variational principles, complex surface geometry, and strong nonlinearity and nonlocality. The speaker will give an overview of theoretical and experimental work on these various systems, highlighting some emerging unifying principles as well as important open problems in theory, experiment, and computation. Particular attention is given to conceptual and computational lessons learned from the connections between integrable systems and the differential geometry of curve motion.

Raymond E. Goldstein
Department of Physics, University of Arizona

3:00 PM-5:00 PM

Ballroom I - Level B

MS6

Spatio-Temporal Chaos: Characterization and Control

Many spatially extended physical systems exhibit complex behavior in time as well as space. Such spatio-temporal chaos has been observed in fluid convection, chemical reactions, wide-area lasers, biological aggregation patterns, etc. and can be described by deterministic PDE. Concepts appropriate for low-dimensional dynamical systems are of limited use in these high-dimensional systems. This minisymposium explores new approaches for characterizing and controlling the dynamics of such systems.The talks will focus on large-scale properties (phase diffusion), emerging localized objects (defects, spirals,...) and their dynamical relevance, as well as the stabilization of embedded periodic states by time-delay feedback.

Organizer: Hermann Riecke
Northwestern University

3:00 Predicting Spiral Chaos in Rayleigh-Benard Convection: A Phase Dynamics Approach to the Onset and Properties of Spatiotemporal Chaos
Michael C. Cross, California Institute of Technology

3:30 Using Finite-Time Lyapunov Dimensions to Measure the Dynamical Complexity of Topological Defects
David Egolf, Cornell University

4:00 Phase Diffusion in Localized Spatio-Temporal Amplitude Chaos of Parametrically Excited Waves
Glen D. Granzow, Northwestern University; and *Hermann Riecke*, Organizer

4:30 Suppressing Spatio-Temporal Chaos Using Time-Delayed Feedback
Michael E. Bleich and *Joshua E. S. Socolar*, Duke University; David Hochheiser and Jerome V. Moloney, University of Arizona

3:00 PM-5:00 PM

Ballroom II - Level B

MS7

Dynamical System Methods for Oceanic and Atmospheric Flows (Part II of II)

(For description see Part I, MS2.)

Organizer: Roberto Camassa
Los Alamos National Laboratory

3:00 A Leading-Order Singular Hamiltonian Perturbation Method in Fluid Dynamics
Onno Bokhove, Woods Hole Oceanographic Institution

3:30 On Hamiltonian Balanced Models of Atmosphere-Ocean Eddy Dynamics
Ian Roulstone, UK Meteorological Office, United Kingdom

4:00 Statistical-Dynamical Methods in Atmospheric Prediction
Joe Tribbia, National Center for Atmospheric Research

4:30 Averaging and Reduced Dynamics in Simple Atmospheric Models
Djoko Wirosoetisno and Theodore G. Shepherd, University of Toronto, Canada

3:00 PM-5:00 PM

Magpie A & B - Level B

MS8

Processing Signals from Noisy Chaotic Systems

Experimental observations are always subject to noise, yet most methods for their interpretation in terms of deterministic chaos were developed to work near the noise free limit; techniques based on Takens's embedding theorem and the various minimization criteria were designed to determine the underlying dynamics treat noise as an afterthought. Here we discuss new results for time series, considering large amplitude measurement (additive) noise as well as dynamical (multiplicative) noise. Talks will range from theory to application including an embedding theorem for noisy systems, a novel look at optimal modeling and prediction, and signal separation applied to noisy ECG data.

Organizers: Mark Muldoon, University of Manchester Institute of Science and Technology, United Kingdom; and Holger Kantz, Max Planck Institute for Physics of Complex Systems, Germany

3:00 Embedding in the Presence of Dynamical Noise
Mark Muldoon, Organizer; J. P. Huke and D. S. Broomhead, University of Manchester Institute of Science and Technology, United Kingdom

3:30 Markov Chain Monte Carlo Methods in Nonlinear Signal Processing
Michael E. Davies, University College London, United Kingdom

4:00 Modeling Noisy Chaotic Data
Holger Kantz, Organizer; and Lars Jaeger, Max Planck Institute for Physics of Complex Systems, Germany

4:30 Processing of Noisy Nonlinear Signals: The Fetal ECG
Thomas Schreiber and Marcus Richter, University of Wuppertal, Germany; and Daniel T. Kaplan, Macalester College

3:00 PM-5:00 PM

Wasatch A & B - Level C

MS9

Nonlinear Oscillators

The purpose of this minisymposium is to review recent advances in the theory of nonlinear oscillators. This will include systems of coupled oscillators as well as oscillators with quasiperiodic forcing. These topics have applications to many areas, including laser de-

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sign, biological processes involving rhythmical phenomenon, such as locomotion and heartbeat, as well as traditional mechanics applications, for example to forced pendula. The mathematical methods involved in these presentations will include asymptotic analysis as well as numerical simulation. The dynamical phenomena will include periodic, quasiperiodic, and chaotic behavior. The intended audience will include researchers interested in dynamical systems and applications.

Organizer: Richard H. Rand
Cornell University

3:00 Symmetric and Asymmetric Dynamics of Linearly Coupled van der Pol Oscillators
Duane W. Storti, Per G. Reinhall, and David M. Sliger, University of Washington

3:30 New Developments in Forced and Coupled Relaxation Oscillations Immersed-Boundary Method
Mark Levi, Rensselaer Polytechnic Institute

4:00 On the Jump Phenomenon in Coupled Oscillators
Adriaan H. P. van der Burgh and Mark Huiskes, Delft University of Technology, The Netherlands

4:30 Transition Curves in the Quasiperiodic Mathieu Equation
Randolf S. Zounes, Cornell University; and *Richard H. Rand*, Organizer

3:00 PM-5:00 PM

Ballroom III - Level B

MS10

Mathematics and Medicine: From the Laboratory to the Clinic

This minisymposium will illustrate the power of combining mathematics and modeling in the biological/medical sciences by examining four major areas: cardiology, neurology, kidney dynamics, and treatment strategies in cancer. Each of these is of importance experimentally and clinically. Current modeling work in these areas ranges from the use of (nonlinear) finite difference equations through ordinary differential equations and differential delay (functional) equations. Unfortunately in almost every specific modeling situation, little is known about the mathematical properties of the model and thus (fortunately) there is usually the opportunity for breaking new ground in mathematical research. In the course of their talks the speakers will illustrate some of these possibilities.

Organizer: Michael C. Mackey
McGill University, Canada

3:00 Use of Mathematical Methods for Protocol Design in Cancer
Zvia Agur, Tel Aviv University, Israel

3:30 Clinical and Mathematical Aspects of Resetting and Entraining Reentrant Tachycardia
Leon Glass, McGill University, Canada

4:00 Modeling the Pupil Light Reflex with Delay Differential Equations
John G. Milton, University of Chicago; and Jacques Bélair, Universite de Montreal, Canada

4:30 Spectral Properties of the Tubuloglomerular Feedback System
Harold E. Layton, Duke University; and E. B. Pitman and L. C. Moore, State University of New York, Stony Brook

3:00 PM-5:00 PM

Chair: Anne Niculae, Northwestern University
Superior B - Level C

CP4

Nonlinear Optics and Solitons I

3:00 Phase Dynamics in Optical Communications
Gregory G. Luther, University of Notre Dame and BRIMS, Hewlett-Packard Laboratories, United Kingdom; Mark S. Alber, University of Notre Dame; Jerrold E. Marsden, California Institute of Technology; and Jonathan Robbins, BRIMS, Hewlett-Packard Laboratories, United Kingdom and Bristol University, United Kingdom

3:20 Timing Jitter Reduction in a Fiber Laser Mode-Locked by an Input Bit Stream
Anne Niculae and William L. Kath, Northwestern University

3:40 Pulse Dynamics in Fiber Lasers
J. Nathan Kutz and Philip Holmes, Princeton University; Michael Weinstein, University of Michigan, Ann Arbor; and Keren Bergman, Princeton University

4:00 Optical Pulse Dynamics in Dispersion Managed Fibers
Tian-Shiang Yang and William L. Kath, Northwestern University

4:20 Switching-Induced Timing Jitter in Nonlinear Optical Loop Mirrors
Michael J. Mills and William L. Kath, Northwestern University

4:40 Nonlinear Polarization-Mode Dispersion in Optical Fibers with Randomly Varying Birefringence
William L. Kath, Northwestern University; P. K. A. Wai, The Hong Kong Polytechnic University, Hong Kong; Curtis R. Menyuk and J. W. Zhang, University of Maryland, Baltimore County

3:00 PM-5:00 PM

Chair: Steven J. Schiff, Children's National Medical Center
Maybird - Level C

CP5

Unstable Periodic Orbits

3:00 Characterization of Blowout Bifurcation by Unstable Periodic Orbits
Yoshihiko Nagai and Ying-Cheng Lai, University of Kansas

3:20 Hopf's Last Hope: Spatio-Temporal Chaos in Terms of Unstable Recurrent Patterns
F. Christiansen, *P. Cvitanoviac*, and V. Putkaradze, Niels Bohr Institute, Denmark

3:40 Detecting Unstable Periodic Orbit in Experimental Data
Paul T. So, Children's National Medical Center; Edward Ott, University of Maryland, College Park; Steven J. Schiff, Children's National Medical Center; Tim Sauer, George Mason University; and Celso Grebogi, University of Maryland, College Park

4:00 From Billiards to Brains - Applying Periodic Orbit Theory to Mammalian Neuronal Networks
Steven J. Schiff, Children's National Medical Center

3:00 PM-5:00 PM

Chair: Colin Sparrow, University of Cambridge, United Kingdom
Superior A - Level C

CP6

Maps

3:00 The Dynamics of Some Digital Filters
Charles Tresser, IBM T. J. Watson Research Center

3:20 Dynamic Period-Doubling Bifurcations of a Unimodal Map
Huw G. Davies and Krishna Rangavajhula, University of New Brunswick, Canada

3:40 Collapsing of Chaos
Guocheng Yuan and James A. Yorke, University of Maryland, College Park

4:00 Nonanalytic Perturbation of Complex Analytic Maps
James Montaldi, Institut NonLineaire de Nice, France; and Bruce B. Peckham, University of Minnesota, Duluth

4:20 Finding All Periodic Orbits of Maps Using Newton Methods: Sizes of Basins
Jacob R. Miller, Shippensburg University; and James A. Yorke, University of Maryland, College Park

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4:40 Dynamics of Non-Expanding Maps and Applications in Discrete Event Theory
Colin Sparrow, University of Cambridge, United Kingdom

7:00 PM-9:00 PM

Ballroom I - Level B

MS11

Spiral-Wave Domains and Filaments: Experiments, Numerics, Theory

The problems of spiral-wave stability and dynamics in two and three dimensions benefit from the interaction of different approaches and on the feedback from its diverse applications. The speakers in this minisymposium bring to bear a variety of methods on these problems. Methods employed include experimental studies of chemical reactions and of specially designed excitable media, numerical work on amplitude and few-species reaction-diffusion equations, and in one case, comparison of numerics with biological patterns. Applications are a main feature of this minisymposium. At least three of the speakers present experimental data, and two speakers will present numerical simulations of three-dimensional patterns. Since the methods vary wildly among the speakers, we are interested in the spectrum of problems encountered and surmounted.

Organizer: Gregory Huber
University of Chicago

7:00 Scaling Relations in Chemical Spirals: Selection and Dispersion
Andrew Belmonte, University of Pittsburgh; Jean-Marc Flesselles, Laboratoire PMMH, ESPCI, France; Vilmos Gaspar, Kossuth Lajos University, Hungary; and Qi Ouyang, Institute Non-Lineaire de Nice, France

7:30 Control of Spiral Territories in Dictyostelium
Herbert Levine, University of California, San Diego

8:00 The Dynamics of Scroll Wave Filaments in the Complex Ginzburg-Landau Equation
Michael Gabbay, Edward Ott, and Parvez Guzdar, University of Maryland, College Park

8:30 Optical Tomography of Chemical Waves in Three Dimensions
Arthur T. Winfree, University of Arizona

7:00 PM-9:00 PM

Ballroom II - Level B

MS12

New Results for Stochastic PDEs

Recent developments in the analysis of stochastic PDEs are highlighted by the speakers in this minisymposium. Rigorous connections between interacting particle systems and measured valued process formally described by parabolic stochastic PDEs with multiplicative noise are discussed, as well as issues of wavefront propagation in such models. Complimentary results for wavefront propagation in hydrodynamic equations, in particular the Burgers equation, with random data are also presented, and a study of the effect of noise on bifurcations in spatially distributed systems is described.

Organizer: Charles R. Doering
University of Michigan, Ann Arbor

7:00 Measure-Valued Processes and Stochastic Modeling of Interacting Particle Systems
Donald Dawson, Fields Institute, Canada

7:30 Width of Wavefronts for Random Travelling Waves
Carl Mueller, University of Rochester; and Roger Tribe, University of Warwick, England

8:00 Front Propagation in Noisy Burgers Type Equations
Jan Wehr and *Jack Xin*, University of Arizona

8:30 Effect of Noise on Bifurcations in Spatially Extended Systems
Grant Lythe, Los Alamos National Laboratory

7:00 PM-9:00 PM

Ballroom III - Level B

MS13

Interplay of Fluid Dynamics and Biology of Plankton Population Models

Plankton constitutes the largest component of the world's biomass, exerting a vital influence on global fluxes of CO2 and other important climatological gases, such as dimethyol sulphate, as well as forming the basis of marine food webs. Mathematical models describing the complex and highly nonlinear population dynamics of plantlike phytoplankton and herbivorous (and sometimes carnivorous) zooplankton vary from many-component systems of PDEs, designed for accurate simulation, to much simpler 3 or even 2 component models, designed to explore crucial processes in the simplest context.The interplay of this light sensitive biology with fluid flow has been little explored as yet and the minisymposium will bring together some of the existing approaches.

Organizer: John Brindley
University of Leeds, United Kingdom

7:00 Diurnal Vertical Migration, A Mechanism for Patchiness in Shear Flows
John Brindley, Organizer; and Louise Matthews, University of Leeds, United Kingdom

7:30 Vertical Migration in Phytoplankton-Zooplankton Interactions
Kathleen Crowe, University of California, Davis

8:00 Chaotic Advection and Plankton Patchiness
Igor Mezic, University of California, Santa Barbara

8:30 Spatial Structure in Oceanic Plankton Populations
Horst Malchow, University of Osnabrueck, Germany

7:00 PM-9:30 PM

Superior A - Level C

MS14

Ulam's Conjecture and the Approximation of Invariant Measures

Continued successful interaction between computational observations of random-like behavior and mathematically rigorous description of dynamical systems will depend on the development of methods for computing the invariant measures of invariant sets whose accuracy can be assessed. This minisymposium will be devoted to a discussion of a method first proposed by Stanislaw Ulam for approximating the absolutely continuous invariant measures of finite-dimensional maps. There will be a discussion of convergence rates in the absolutely continuous case, and presentation of recent results on approximation of measures and attractors where the Birkhoff Ergodic theorem holds almost everywhere (Lebesgue). Our purpose is to present an easily implemented alternative to the computation of invariant measures (histograms) by box counting-a procedure for which there are to our knowledge no general estimates. We show how the method can be used to calculate Lyapunov exponents. Highlighted will be ex-

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tensions of the original method to multi-dimensional maps and set-valued maps. Convergence rates of the method will be discussed in the absolutely continuous case, and results on the approximation of attractors and invariant measures will be presented for the singular case.

Organizer: Fern Y. Hunt
National Institute of Standards and Technology

7:00 Computing Physical Measures of Mixing Multidimensional Systems with an Application to Lyapunov Exponents
Gary Froyland, The University of Western Australia, Australia

7:30 A Finite Element Method for the Frobenius-Perron Operator Equation
Jiu Ding, University of Southern Mississippi; and Aihui Zhou, Academia Sinica, People's Republic of China

8:00 Approximating Attractors and Chain Transitive Invariant Sets with Ulam's Method
Fern Y. Hunt, Organizer

8:30 Markov Finite Approximation of Frobenius-Perron Operators and Invariant Measures for Set-Valued Dynamical Systems
Walter Miller, Howard University

9:00 Cone Conditions and Error Bounds for Ulam's Method
Rua D. A. Murray, University of Cambridge, United Kingdom

7:00 PM-9:00 PM

Chair: William L. Kath, Northwestern University
Magpie A & B - Level B

CP7

Nonlinear Optics and Solitons II

7:00 Noisy Quasi-Periodicity in the Simulation of the Discrete Nonlinear Schrödinger Equation
Makoto Umeki, University of Tokyo, Japan

7:20 Soliton Stability in Optical Transmission Lines using Semiconductor Amplifiers and Fast Saturable Absorbers
S. K. Turitsyn, Heinrich Heine Universität Dusseldorf, Germany

7:40 Vector Solitons and Their Internal Oscillations
Jianke Yang, University of Vermont

8:00 The Application of the Direct Scattering Transform to the NRZ-to-Soliton Data Conversion Problem
S. Burtsev and Roberto Camassa, Los Alamos National Laboratory; and P. Mamyshev, Bell Laboratories, Lucent Technologies

8:20 Mass Exchanges Among Korteweg-de Vries Solitons
Peter D. Miller, The Australian National University, Australia; and Peter L. Christiansen, The Technical University of Denmark, Denmark

7:00 PM-9:00 PM

Chair: M. C. Depassier, Universidad Catolica de Chile, Chile
Superior B - Level C

CP8

Hamiltonian Systems

7:00 Instabilities and Degeneracies of the 4-Dimensional Stochastic Web
Sergey Pekarsky, The Weizmann Institute of Science, Israel and California Institute of Technology; and Vered Rom-Kedar, The Weizmann Institute of Science, Israel

7:20 On Smooth Hamiltonian Flows Limiting to Hyperbolic Billiards
Dmitry Turaev and *Vered Rom-Kedar*, The Weizmann Institute of Science, Israel

7:40 Variational Principle for Bifurcations in One Dimensional Hamiltonian Systems
R. D. Benguria and *M. C. Depassier*, Universidad Catolica de Chile, Chile

8:00 The Hamiltonian and Lagrangian Approaches to the Dynamics of Nonholonomic Systems
Wang-Sang Koon, University of California, Berkeley; and Jerrold E. Marsden, California Institute of Technology

8:20 Approximation of KAM Tori and Aubry-Mather Sets by Periodic Solutions of a Perturbed Burgers' Equation
Vadim Zharnitsky, Los Alamos National Laboratory

8:40 A Leading-Order Singular Hamiltonian Perturbation Method in Fluid Dynamics
Onno Bokhove, Woods Hole Oceanographic Institution

7:00 PM-9:00 PM

Chair: Reggie Brown, College of William and Mary
Wasatch A & B - Level C

CP9

Synchronization I

7:00 New Bifurcations from an Invariant Subspace
Philip J. Aston and Peter Ashwin, University of Surrey, United Kingdom; and Matthew Nicol, University of M anchester Institute of Science and Technology, United Kingdom

7:20 Signal Masking Using Synchronized Chaos-Proof and Analysis by Perturbation Theory
Mohamed A. Ali, Cornell University

7:40 Determining Coupling that Guarantees Synchronization Between Identical Chaotic System Method
Reggie Brown, College of William and Mary

8:00 Automatic Gain Control using Synchronized Chaos
Ned J. Corron, Dynetics, Inc., Huntsville

8:20 On Generalized Synchronization of Chaos in Mutually Coupled Systems
Nikolai F. Rulkov, Mikhail M. Sushchik Jr., and Henry D. I. Abarbanel, University of California, San Diego

8:40 Stick-Slip Dynamics as an Elastic Excitable Media
Julyan H. E. Cartwright, Emilio Hernandez Garcia, and *Oreste Piro*, Universitat de les Illes Balears, Spain

7:00 PM-9:00 PM

Chair: Brian R. Hunt, University of Maryland, College Park
Maybird - Level C

CP10

Attractors, Fractals, and Dimensions

7:00 Nondifferentiable Attractors, Data Filtering, and Fractal Dimension Increase
Louis M. Pecora and Thomas L. Carroll, Naval Research Laboratory

7:20 Crisis in Quasiperiodically Forced Systems
Ulrike Feudel, Universität Potsdam, Germany

7:40 Invariant Graphs And Strange Nonchaotic Attractors for Quasiperiodically Forced Systems
Jaroslav Stark, University College London, United Kingdom

8:00 Blowout Bifurcation Route to Strange Nonchaotic Attractors
Tolga Yalcinkaya and Ying-Cheng Lai, University of Kansas

8:20 Which Dimension of Fractal Measures are Preserved by Typical Projections?
Vadim Yu. Kaloshin, Princeton University; and Brian R. Hunt, University of Maryland, College Park

8:40 Fractal Dimensions of Chaotic Saddles of Dynamical Systems
Brian R. Hunt, Edward Ott, and James A. Yorke, University of Maryland, College Park

9:00 Determining General Fractal Dimensions from Small Data Sets
A. J. Roberts, University of Southern Queensland, Australia

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8:30 AM-9:30 AM

Chair: Robert Borrelli, Harvey Mudd College

Ballroom I, II, III - Level B

IP3

Teaching Dynamical Systems to Undergraduates

For the past several years, we have offered a two-part course in dynamical systems to lower-level undergraduate students at Boston University. The first course is a dynamical systems oriented version of the sophomore-level differential equations course. In this course, many of the exact methods of solution of ODES have been replaced by more numerical and qualitative techniques. The second course is a sophomore-junior-level course in discrete dynamics. We view this course as a prelude to the standard undergraduate real analysis course. Students are introduced to such topics as abstract metric spaces, dense sets, continuity, etc. in the fairly concrete arena of iteration of real and complex functions. In this presentation, the speaker will discuss some of the issues involved in organizing such courses, including relations with client disciplines.

Robert L. Devaney
Department of Mathematics
Boston University

10:00 AM-12:00 PM

Magpie A & B - Level B

MS15

Diffusion and Turbulence on Water Surfaces

The purpose of the minisymposium is to focus on the motion of particles, floats, and drifters on a turbulent water surface. Results obtained for the self-diffusivity by tracking drifters in the ocean and for the relative diffusivity by tracking pairs of drifters all show that the motion is far from being Brownian. In the geophysical dynamical regime, at time scales between roughly 1 day and 10 days and length scales between roughly 10 km and 100 km, the drifter motion possesses significant persistence ('memory'), which is not present in ordinary Brownian motion. A similar persistence is observed in laboratory experiments, where turbulent surface waves are formed and sustained by external forcing. Also here measurements of self-diffusivity and relative diffusivity of floating particles reveal a non-Brownian motion.We wish to compare the results from upper-ocean studies with those from laboratory experiments and with related theoretical results for wave turbulence.

Organizer: Preben Alstrom
Niels Bohr Institute, Denmark

10:00 Drifter Trajectories in Geophysical Flows
Antonello Provenzale, Istituto di Cosmogeofisica, Italy

10:30 Motion of Floating Particles on a Turbulently Driven Fluid
Walter I. Goldburg and Cecil Cheung, University of Pittsburgh

11:00 Particle Motion in Capillary Surface Waves
Preben Alstrom, Organizer; Mogens T. Levinsen and Elsebeth Schröder, Niels Bohr Institute, Denmark

10:00 AM-12:00 PM

Ballroom I - Level B

MS16

Phase Dynamics and Synchronization in Chaotic Systems

Since the time of Huygens' pioneering work on synchronization, there has been much progress in synchronization phenomena, also of chaotic systems. The speakers in this minisymposium will present new phenomena of phase synchronization and their relation to complete synchronization.The emphasis is also on phase dynamics in complex spatio-temporal structure formation.

Organizer: Jürgen Kurths
Universität Postdam, Germany

10:00 Phase Synchronization of Chaotic Systems
Jürgen Kurths, Organizer

10:30 Synchronization Transitions in Coupled Chaotic Oscillators: From Phase to Compete Synchronization
Michael Rosenblum, Universität Potsdam, Germany and Russian Academy of Sciences, Russia

11:00 Long-Range Rotating Order in Extensively-Chaotic Systems
Hugues Chaté, Centre d'Etudes de Saclay, France

11:30 Spiral Waves in Chaotic Systems
Raymond Kapral, University of Toronto, Canada

10:00 AM-12:00 PM

Ballroom II - Level B

MS17

Dynamics of Cortical Neural Networks (Part I of II)

Recent theoretical studies have been actively engaged in understanding collective phenomena of large neural networks, that are involved in different behavioral states and sensory information processing. In this minisymposium, eight talks in two related sessions will be focused on neurodynamical processes such as synchronous oscillations and wave propagation. We would like to illustrate how a novel network behavior may arise due to particular aspects of complex single neuron dynamics and/or synaptic circuits, such as neural firing patterns (e.g. spike adaptation, bursting), synaptic kinetics and depression, cortical local circuit, random sparse connectivity, and recurrent inhibition.

Organizers: Xiao-Jing Wang, Brandeis University; David Terman, Ohio State University, Columbus; and John Rinzel, National Institutes of Health

10:00 Rhythms and "Lurching" Waves in the "Sleeping" Thalamic Slice
John Rinzel and Xiao-Jing Wang, Organizers; and David Golomb, Ben-Gurion University, Israel

10:30 Synchronous and Asynchronous States in a Network of Spiking Neurons
Wulfram Gerstner, Swiss Federal Institute of Technology, Switzerland

11:00 Image Segmentation Based on Oscillatory Correlation
David Terman, Organizer; and DeLiang Wang, Ohio State University

11:30 Saddle-Node Bifurcations and Wave Propagation in Model Cortical Column Structures
Frank C. Hoppensteadt, Arizona State University

10:00 AM-12:00 PM

Ballroom III - Level B

MS18

Pattern Formation and Singular Perturbations

Many physical systems exhibit dynamics on multiple time scales and/or multiple length scales. Examples arise in nonlinear fiber optics, multi-degree-of-freedom Hamiltonian systems, chemical reactions, fluid dynamics, and neurophysiology. In this minisymposium, the speakers will address important current

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nonlinear dynamics questions in problems from several of these areas. For systems modeled by reaction diffusion equations, spatial patterns evolving in complex time-dependent ways will be discussed. In addition, a number of speakers will focus on the mathematical theory and applications of the existence and stability of time asymptotic stationary patterns. These states include traveling waves, their concatenations, and spatially periodic states. In those systems modeled by Hamilton's equations, speakers will focus on the existence and stability of a diverse array of multiple pulse orbits and where they arise in applications. Mathematically, the methods used in these studies range from variational techniques and matched asymptotic expansions to analytical and geometrical methods in stability theory and singular perturbation theory. Theoretical tools from complex dynamics and electromagnetism theory also play significant roles.

Organizers: Arjen Doelman, University of Utrecht, The Netherlands; Tasso Kaper, Boston University; and Todd Kapitula, University of New Mexico, Albuquerque

10:00 Singular Limits of Phase Equations for Patterns Far from Threshold
Nicholas M. Ercolani and Robert Indik, University of Arizona; Alan Newell, University of Warwick, England; and Thierry Passot, Observatoire de Nice, France

10:30 Self-Replicating Spots
John Pearson, Los Alamos National Laboratory

11:00 Stability Analysis of Pulse Solutions of the Gray-Scott Model
Robert Gardner, University of Massachusetts, Amherst

11:30 Oscillatory Instabilities of Labyrinthine Fronts
David Muraki, Courant Institute of Mathematical Sciences, New York University

10:00 AM-12:00 PM

Wasatch A & B - Level C

MS19

Nonlinear Dynamics of Large Fluctuations

Substantial progress has been made recently in understanding large fluctuations in nonlinear systems. It came through application of the methods of nonlinear dynamics and catastrophe theory. An important concept in describing large fluctuations is the most probable, or optimal, fluctuational path to a given state. For large fluctuations, the pattern of optimal paths plays a role similar to that of the phase portrait in nonlinear dynamics. For nonequilibrium physical and chemical systems this pattern generically has singular features. Their analysis and applications of the results to the problems of escape from a metastable state and signal enhancement by fluctuating systems will be discussed.

Organizer: Mark I. Dykman
Michigan State University

10:00 The Stochastic Manifestations of Chaos
Linda E. Reichl, University of Texas, Austin

10:30 Signal Enhancement by Large Fluctuations
Peter V. E. McClintock, Lancaster University, United Kingdom

11:00 Periodic Modulation of the Rate of Noise-Induced Escape through an Unstable Limit Cycle
Robert S. Maier, University of Arizona

11:30 Critical Behavior of the Distribution of Fluctuational Paths
Mark I. Dykman, Organizer; and Vadim N. Smelyanskiy, Michigan State University

10:00 AM-12:00 PM

Chair: Manfred F. Goz, Princeton University
Maybird - Level C

CP11

Nonlinear Waves

10:00 Recent Progress in Multi-Dimensional Mode Conversion
Allan N. Kaufman, Alain J. Brizard, and Jim Morehead, Lawrence Berkeley National Laboratory; and Eugene R. Tracy, College of William and Mary

10:20 Local Singularities in Breaking Waves
Daniel P. Lathrop, Emory University

10:40 A Robust Heteroclinic Cycle in an $O(2) \times Z_2$ Steady-State Mode Interaction
P. Hirschberg and *Edgar Knobloch*, University of California, Berkeley

11:00 Two-Period Quasiperiodic Attractors of Weakly Nonlinear Gas Dynamics Equations
Michael G. Shefter and Rodolfo R. Rosales, Massachusetts Institute of Technology

11:20 The Strongly Attracting Character of Large Amplitude Nonlinear Resonant Acoustic Waves Without Shocks
Dimitri D. Vaynblat and Rodolfo R. Rosales, Massachusetts Institute of Technology

11:40 A Nonlinear Wave Equation Arising in Two-Phase Flow
Manfred F. Goz, Princeton University

10:00 AM-12:00 PM

Chair: Yuri Latushkin, University of Missouri, Columbia
Superior A - Level C

CP12

Invariant Measures and Ergodicity

10:00 An Exact Formula for the Essential Spectral Radius of the Matrix Ruelle Operator on Spaces of Hoelder and Differentiable Vector-Functions
Yuri Latushkin, University of Missouri, Columbia

10:20 Transfer Operators in Conformal Dynamics
Marius Urbanskij, University of North Texas

10:40 On the Lax-Phillips Scattering Theory of Uniformly Hyperbolic Chaotic Dynamics
Thomas J. Taylor, Arizona State University; and Duk-Hyung Lee, Indiana Wesleyan University

11:00 Convergence of the Transfer Operator for Rational Maps
Nicolai Haydn, University of Southern California

10:00 AM-12:00 PM

Chair: Adam S. Landsberg, Haverford College
Superior B - Level C

CP13

Applications in Physics

10:00 Relaxation of Magnetic Knots to Minimal Braids
Renzo L. Ricca, University College London, United Kingdom

10:20 Bifurcations and Instabilities in Moving Vortex Lattice
Igor Aranson and Valerii Vinokur, Argonne National Laboratory

10:40 Flux Creep in 2-D Josephson Junction Arrays
Adam S. Landsberg, Haverford College; and Kurt Wiesenfeld, Georgia Institute of Technology

11:00 Geometrical Phase in Twisted Pairs used in Communication Networks
Mayank Sharma and *D. Subbarao*, Indian Institute of Technology, India

11:20 Transonic Solutions for a Quantum Hydrodynamic Semiconductor Model
Peter Szmolyan, Technische Universität Wien, Austria

11:40 Synchronization by Disorder in Parallel Arrays of Josephson Junctions
Yuri Braiman, Emory University

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1:30 PM-2:30 PM

Chair: Peter Bates, Brigham Young University

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IP4

Scaling Exponents in Turbulence

The speaker will discuss some of the current issues regarding scaling exponents in hydrodynamical equations, including passive scalars, active scalars and two dimensional turbulence.

Peter S. Constantin
Department of Mathematics
University of Chicago

2:30 PM-3:30 PM

Chair: John Rinzel, National Institutes of Health
Ballroom I, II, III - Level B

IP5

Stochastic Resonance in Sensory Biology

In certain nonlinear systems, of which neurons are an example, the addition of random fluctuations, or "noise", can enhance the detection and transmission efficiency of the neural networks designed to perceive weak stimuli. This counterintuitive statistical process, called "stochastic resonance" (SR), is well established in a variety of physical systems. Recently it has been observed in the sensory nervous systems of two arthropods, crayfish and crickets, and may be deeply linked to the evolution of all sensory networks.

This talk will focus on the experimental observations at two levels: the individual sensory neuron, and the next higher network level, the terminal ganglion,and introduce human perception of SR in noisy visual images. A simple statistical theory will be used throughout to interpret the experimental results.

Frank Moss
Center for Neurodynamics and Department of Physics and Astronomy
University of Missouri, St. Louis

4:00 PM-6:00 PM

Magpie A & B - Level B

MS20

Computing Invariant Manifolds

Geometric descriptions of dynamical systems include varied types of invariant manifolds, including stable and unstable manifolds of equilibrium points and periodic orbits, normally hyperbolic invariant manifolds, manifolds of equilibria in families and bifurcation sets in multiparameter families. This minisymposium will highlight computational methods to determine invariant manifolds of dimension larger than one. The algorithmic basis for such computations is not firmly established and is undergoing rapid evolution. The problems entail significantly greater geometric complexity than is encountered in the computation of invariant curves. The speakers will describe their experiences in implementing calculations of two dimensional invariant manifolds on example problems.

Organizer: John Guckenheimer
Cornell University

4:00 Computation of Heteroclinic Two-Dimensional Invariant Manifold Interactions
Mark E. Johnson, Princeton University; Michael S. Jolly, Indiana University, Bloomington; Ioannis G. Kevrekidis, Princeton University; and John Lowengrub, University of Minnesota, Minneapolis

4:30 Computing Invariant Manifolds of Saddle-Type
Hinke Osinga, University of Minnesota, Minneapolis

5:00 Computing Stable Sets of Noninvertible Mappings
Frederick J. Wicklin and Chia-Hsing Nien, University of Minnesota, Minneapolis

5:30 Stable and Unstable Manifolds of Halo Orbits in the Circular Restricted Three-body Problem
Robert Thurman and *Patrick Worfolk*, University of Minnesota, Minneapolis

4:00 PM-6:00 PM

Ballroom I - Level B

MS21

Josephson Junction Arrays: Progress and Puzzles

Josephson junction arrays are superconducting nonlinear circuits which hold promise for a variety of applications in extreme high frequency electronics. As a paradigm of coupled oscillator systems, Josephson junction arrays have attracted increasing attention in the dynamics community. At the same time, experimental progress on these superconducting circuits has blossomed. These two lines of inquiry are beginning to overlap in an essential way. This minisymposium features three leading experimentalists in the field to report both recent results and open questions. The purpose is to focus attention on issues that arise in the study of real Josephson junction arrays, as described by the foremost applied practitioners in the field. (These are speakers the dynamics community is rarely exposed to.) The intended audience is anyone interested in real world applications of coupled oscillator systems.

Organizer: Kurt A. Wiesenfeld
Georgia Institute of Technology

4:00 Generation of Submillimeter Wave Radiation Using Linear Phase-Locked Josephson Junction Arrays
James Lukens, State University of New York, Stony Brook

4:30 Josephson Junction Arrays: Practical Devices and Nonlinear Dynamics
Terry P. Orlando, Massachusetts Institute of Technology

5:00 Dynamical Properties of Two-Dimensional Josephson-Junction Arrays
A. B. Cawthorne, P. Barbara, and *Chris J. Lobb*, University of Maryland, College Park

4:00 PM-6:00 PM

Wasatch A & B - Level C

MS22

Integrable Systems Methods for Curve Evolution

This minisymposium proposes to discuss different aspects of the interaction between soliton equations and the properties and dynamics of space curves. Interest in modeling curves and knots by means of completely integrable equations has revived in recent years with applications to topological fluid dynamics, the evolution of vortex filaments and vortex patches, and to the modeling of DNA and macromolecules. This minisymposium is directed to an audience whose main interests are nonlinear dynamics and completely integrable equations, knot theory and its applications in biology and fluid dynamics, applied dynamical systems and their connections to differential geometry and topology of curves and surfaces. Its principal purpose is to encourage applications of well-established techniques of integrable systems to a variety of problems in which curve dynamics and knots arise. It also advocates that, on the one hand, a geometric

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interpretation of soliton equations can shed new light on their structure; on the other hand, their large families of special solutions, such as the solitons and the multi-phase solutions, can provide an important tool for the study of the topological properties of related curves.

Organizers: Annalisa Calini, University of Charleston; and Thomas Ivey, Case Western Reserve University

4:00 **Geometric Realizations of Fordy-Kulish Integrable Systems, Sym-Pohlmeyer Curves, and Related Variation Formulas (Part I)**
Joel Langer, Case Western Reserve University; and Ron Perline, Drexel University

4:30 **Geometric Realizations of Fordy-Kulish Integrable Systems, Sym-Pohlmeyer Curves, and Related Variation Formulas (Part II)**
Joel Langer, Case Western Reserve University; and *Ron Perline*, Drexel University

5:00 **Homotopies and Knot Types of Elastic Rods**
Thomas Ivey, Organizer

5:30 **Backlund Transformations of Knots of Constant Torsion**
Annalisa Calini and Thomas Ivey, Organizers

4:00 PM-6:00 PM

Ballroom II - Level B

MS23

Dynamics of Cortical Neural Networks (Part II of II)

(For description, see Part I, MS17.)

Organizers: Xiao-Jing Wang, Brandeis University; David Terman, Ohio State University, Columbus; and John Rinzel, National Institutes of Health

4:00 **Synaptically Induced Bistability and Transition to Repetitive Activity**
Bard Ermentrout and Jim Uschock, University of Pittsburgh

4:30 **Modeling Cortical 40 Hz Oscillations: Pacemaker Neurons and Synaptic Synchronization**
Xiao-Jing Wang, Organizer

5:00 **Pattern Generation by Two Coupled Time-Discrete Neural Networks with Synaptic Depression**
Walter Senn and Jürg Streit, University of Bern, Switzerland

5:30 **The Role of Spike Adaptation in Shaping Spatiotemporal Patterns of Activity in Cortex**
David Hansel, Centre de Physique Théorique, Ecole Polytechnique, France

4:00 PM-6:00 PM

Ballroom III - Level B

MS24

Teaching Differential Equations Dynamically

The advent in the early 80s of widely accessible computer graphics revolutionized differential equations, and therefore their teaching. Now we easily see many solutions simultaneously, even for equations that do not have solutions in closed form. Visual perspective and geometric content extend our capabilities; we can handle more complicated equations and more general dynamical systems. Bifurcation and chaos are no longer relegated to graduate school; these topics are commonplace in introductory courses. Far beyond our classrooms, the new approach helps scientists in numerous programs not traditionally mathematical (e.g., FDA, NIH, U.S. Geological Survey) to make models with dynamical systems and experiment with parameters. This minisymposium will be of interest to nonacademic scientists who want to know what is going on in the classroom, and how they or their colleagues might access it, as well as our university colleagues.

Organizer: Beverly H. West
Harvey Mudd College and Cornell University

4:00 **ODE Architect: CODEE'S Multimedia Package**
Robert L. Borrelli, Harvey Mudd College

4:30 **How to Make a Pendulum Do Anything You Want**
John H. Hubbard, Cornell University

5:00 **Teaching ODE's with the WWW and A Calculator-Based Laboratory**
Frank Wattenberg, Carroll College and Montana State University

5:30 **Visualization and Verification, with Mathematica, of Solutions to Differential Equations**
Stan Wagon, Macalester College

4:00 PM-6:00 PM

Chair: Anne C. Skeldon, City University, United Kingdom
Maybird - Level C

CP14

Convection and Hexagonal Patterns

4:00 **Takens-Bogdanov Bifurcation on the Hexagonal Lattice for Double-Layer Convection**
Yuriko Y. Renardy and Michael Renardy, Virginia Polytechnic Institute and State University; and Kaoru Fujimura, Japan Atomic Energy Research Institute, Japan

4:20 **Non-Potential Effects in Pattern Formation**
Alexander Golovin, Northwestern University; Asaf Hari, Alexander Nepomnyaschchy, *Alexander Nuz*, and Leonid Pismen, Technion-Israel Institute of Technology, Israel

4:40 **Multiplication of Defects in Hexagonal Patterns**
A. A. Nepomnyashchy, Technion-Israel Institute of Technology, Israel; P. Colinet and J. C. Legros, Universite Libre de Bruxelles, Belgium

5:00 **Patterns in Long Wavelength Convection**
Anne C. Skeldon, City University, United Kingdom; and Mary Silber, Northwestern University

5:20 **Ginzburg-Landau Equations for Hexagonal Patterns**
Blas Echebarria and Carlos Perez-Garcia, Universidad de Navarra, Spain

5:40 **The Takens-Bogdanov Bifurcation in Long-Wave Theory**
Jean-Luc Thiffeault, University of Texas, Austin; and Neil J. Balmforth, University of Nottingham, United Kingdom

4:00 PM-6:00 PM

Chair: Tasso Kaper, Boston University
Superior B - Level C

CP15

Pattern Formation and Singular Perturbations II

4:00 **An Accurate Description of Slow-Motion Dynamics in Singularly Perturbed Reaction-Diffusion Systems**
Björn Sandstede, Weierstrass Institute for Applied Analysis and Stochastics, Germany

4:20 **Irregular Jumping in the Perturbed Nonlinear Schrödinger Equation**
George Haller, Brown University

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4:40 Singularly Perturbed and Non-Local Modulation Equations
V. Rottschafer and A. Doelman, University of Utrecht, The Netherlands

5:00 Multiple-Pulse Homoclinic and Periodic Orbits in Singularly Perturbed Systems
Cristina Soto-Trevino, Boston University

5:20 Homotopy Classes for Stable Connections between Hamiltonian Saddle-Focus Equilibria
R. VanderVorst, Georgia Institute of Technology and University of Leiden, The Netherlands; W. D. Kalies, California Polytechnic State University, San Luis Obispo; and J. Kwapisz, Georgia Institute of Technology

5:40 Existence and Stability of Singular Heteroclinic Orbits for the Ginzburg-Landau Equation
Todd Kapitula, University of New Mexico, Albuquerque

4:00 PM-6:00 PM

Chair: Brian F. Farrell, Harvard University
Superior A - Level C

CP16
Fluids I

4:00 Integrability and Non-Integrability in Bubble Dynamics
Alexander R. Galper, Tel-Aviv University, Israel

4:20 Asymptotic Focusing of Particles in a Wake Flow
T. J. Burns, R. W. Davis and E. F. Moore, National Institute of Standards and Technology

4:40 Perturbation Growth in Non-Autonomous Geophysical Flows
Petros J. Ioannou, Harvard University

5:00 Non-Normal Dynamics of Eddy Variance and Transport Properties in Geophysical Flows
Brian F. Farrell, Harvard University

5:20 Experimental Evidence for Chaotic Scattering in a Fluid Wake
John C. Sommerer, Hwar-Ching Ku, and Harold E. Gilreath, Johns Hopkins University

5:40 Mixing and Transport Rates for a Marangoni-driven Chaotic Flow
Gerard Alba-Soler and August Palanques-Mestre, University of Barcelona, Spain

6:00 PM-7:00 PM

Golden Cliff - Level B

Business Meeting
SIAM Activity Group on Dynamical Systems

Tuesday, May 20

8:30 AM-9:30 AM

Chair: Kurt Wiesenfeld, Georgia Institute of Technology
Ballroom I, II, III - Level B

IP6
Bucket Brigade Production Lines

Bucket brigade manufacturing is a way of organizing workers on a production line, in which there are fewer workers than stations and each worker carries his work from station to station. The order on a line is fixed, We address the problem of the optimal sequencing of workers on a line so that the production rate of such line would be maximal. The performance of such production lines can be effectively described by the dynamical system defined on a simplex. The application of ideas of dynamical systems theory resulted in increased production rate of such lines in the apparel industry. The randomized version of this model proved to be efficient for coordinating pickers in the warehouses that resulted in the essential increase of pick rates. The speaker will explain why this happened.

Leonid A. Bunimovich
Southeast Applied Analysis Center and School of Mathematics
Georgia Institute of Technology

10:00 AM-12:00 PM

Ballroom I - Level B

MS25
Dynamics of Curves and Filaments

The motion and dynamical behavior of curves and filaments provide excellent models for physical problems ranging from DNA conformation (10^{-8} meters) to motion of solar flux tubes and sunspot formation (10^{8} meters), with many more relevant examples in between. Although a classical subject, recent advances in experimental, computational, and analytical techniques have brought increased attention to the study of the dynamics of curve and filament systems. In this minisymposium a thin cross-section of these new methods and results will be presented with an emphasis on applications to physical systems. The purpose of this minisymposium is to acquaint the general applied math community with some of the extensive recent work on curve dynamics, particularly curves with twist, and its relation to physical systems.

Organizer: Isaac Klapper
Montana State University

10:00 Title to be determined
L. Mahadevan, Massachusetts Institute of Technology

10:30 Nonlinear Dynamics of Elastic Filament
Alain Goriely and Michael Tabor, University of Arizona

11:00 Curve Dynamics and Gene Regulation
Gadi Fibich and Danny Petrasek, University of California, Los Angeles; and Isaac Klapper, Organizer

11:30 Removing the Stiffness of Curvature in 3-D Filament Calculations
Thomas Y. Hou, California Institute of Technology; Isaac Klapper, Organizer; and Hui Si, California Institute of Technology

10:00 AM-12:30 PM

Ballroom II - Level B

MS26
Random Dynamical Systems

This minisymposium will focus on both theory and applications of random dynamical systems. During the past ten years there has been a great interest and real progress in stochastic bifurcation theory, stochastic normal form theory and control of stochastic systems. This progress in the theory has led to the development of reliable numerical algorithms for computing characteristic quantities in stochastic dynamical systems. The speakers in this minisymposium will address the theoretical developments in the area of stochastic bifurcations, stochastic functional equations, and random attractors; and the applications of random dynamical systems to engineering systems.

Organizer: N. Sri Namachchivaya
University of Illinois, Urbana

10:00 The Role of Attractors in Stochastic Bifurcation Theory
Ludwig Arnold, University of Bremen, Germany

10:30 Bifurcation Theory for Stochastic Differential Equations
Peter Baxendale, University of Southern California

11:00 Random Dynamical Systems in Engineering
S. T. Ariaratnam, University of Waterloo, Canada

11:30 Self Stabilization of Stochastic Systems
Volker Wihstutz, University of North Carolina, Charlotte

12:00 Attractors for Random Dynamical Systems
Björn Schmalfusk, University of Bremen, Germany

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10:00 AM-12:00 PM

Wasatch A & B - Level C

MS27
Slow Evolution in Conservative Systems

A common paradigm for the description of physical systems is that of a slow evolution through families of relatively simple states, like equilibrium states or states of periodic motion. The mathematical foundation for approximating this evolution is fairly well established if the underlying systems are dissipative. There are numerous examples, however, for which the underlying systems are conservative. The mathematical foundations for approximating the slow evolution are not well established in this case, except for one-degree-of-freedom systems, where the method of averaging is effective. This minisymposium is intended to describe what is presently known and to present physically important examples, including those in which the simple states undergo a transition from stable to unstable, illustrating the mathematical complexities that can arise in these contexts.

Organizer: Norman R. Lebovitz
University of Chicago

10:00 Slow Evolution Near Families of Stable Equilibria of Hamiltonian Systems
Norman R. Lebovitz, Organizer

10:30 Weakly Unstable Systems in the Presence of Neutrally Stable Modes
John D. Crawford, University of Pittsburgh

11:00 Some Experiments on Nonstationary Vibrations in a Single Degree-of-Freedom Nonlinear Systems
Anil K. Bajaj, Mark Hood, and Patricia Davies, Purdue University

11:30 Accurate Phase After Slow Passage Through Subharmonic Resonance
Jerry D. Brothers, Raytheon E-Systems; and *Richard Haberman*, Southern Methodist University

10:00 AM-12:00 PM

Ballroom III - Level B

MS28
Biological Microswimming

There are certain mystery swimmers — micro-organisms for which the means of propulsion are not understood. The underlying dynamics for swimming are defined by the Stokes equations with time-varying boundary conditions. A geometric reformulation of the swimming problem due to Shapere and Wilczek in 1989 allowed for a fresh look from a "gauge-theoretic" perspective. Recent advances obtained using this and other perspectives will be presented. The minisymposium will also provide a forum for mathematicians and biologists to interact and present what they see as the important problems in this area. The current mathematical methods employed are chiefly analytic in nature and bog down for animals with complicated shapes. On the other hand the important biological questions are often of a rough qualitative nature. One of the main problems in this area is to know what the problems are. This is only possible through sustained communication between biologists and mathematicians or physicists.

Organizers: Richard W. Montgomery, University of California, Santa Cruz; and Jair Koiller, Laboratorio Nacional de Computacao Cientifica, Brazil

10:00 Self-Propulsion of Spherical Swimmers Using Surface Deformations
Aravi Samuel, Howard Stone; and Howard Berg, Harvard University

10:30 Discovering the Mysteries of Swimming Microorganisms on the Beaches of Rio
Kurt Ehlers, Laboratorio Nacional de Computacao Cientifica, Brazil

11:00 Geometry of Microswimming
Richard W. Montgomery, Organizer

11:30 A Spectral Method for Stokes Flows and Applications to Microswimming
Jair Koiller, Organizer; Joaquin Delgado, UNAM, Mexico; and Marco Raupp, Laboratorio National de Computacao Cientifica, Brazil

10:00 AM-12:00 PM

Maybird - Level C

MS29
Bifurcation Theory and Systems of Nonlinear Conservation Laws

Systems of two conservation laws in one space dimension are PDEs without viscosity that arise in modeling many physical systems, such as gas dynamics, three-phase flow in a porous medium, elastic strings, and phase transitions. The fundamental initial-value problem for these systems is the Riemann problem, in which the initial data are piecewise constant with a single jump. Riemann solutions can include shock waves, which are regarded as admissible if they correspond to traveling wave solutions when viscosity is added. This criterion may conflict with the classical Lax criterion. The speakers will discuss the use of vector field bifurcation theory to elucidate the wave structure of Riemann solutions.

Organizer: Stephen Schecter
North Carolina State University

10:00 An Application of Vectorfield Bifurcation to Conservation Laws that Change Type
Barbara Lee Keyfitz, University of Houston

10:30 On the Influence of Viscosity on Riemann Solutions of Nonlinear Conservation Laws
Suncica Canic, Iowa State University

11:00 The Role of Polycycles in Nonuniqueness of Riemann Solutions
Arthur Azevedo, Universidade de Brasilia, Brazil; Dan Marchesin, Instituto de Matematica Pura e Aplicada, Brazil; *Bradley Plohr*, State University of New York, Stony Brook; and Kevin Zumbrun, Indiana University

11:30 Riemann Problem Solutions of Codimensions 0 and 1
Stephen Schecter, Organizer; Dan Marchesin, Instituto de Matematica Pura e Aplicada, Brazil; and Bradley Plohr, State University of New York, Stony Brook

10:00 AM-12:00 PM

Chair: James A. Walsh, Oberlin College
Superior A - Level C

CP17
Teaching Dynamics

10:00 Circle Homeomorphisms and Advanced Calculus
James A Walsh, Oberlin College

10:20 Development of a Laboratory Based Course in Nonlinear Dynamical Systems
N. Fleishon, J. McDill, K. Morrison, R. Schoonover, *J. P. Sharpe* and N. Sungar, California Polytechnic State University

10:40 UG Course at IIT Delhi on Self-Organising Dynamical Systems
D. Subbarao, Indian Institute of Technology, India

11:00 Controlling the Chaotic Logistic Map, An Undergraduate Project
Erik M. Bollt, United States Military Academy

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10:00 AM-12:00 PM

Chair: Tomas Gedeon, Montana State University
Superior B - Level C

CP18
Neural and Excitable Systems I

10:00 Phase Synchronization in an Array of Coupled Integrate-and-Fire Neurons with Dendritic Structure
Paul C. Bressloff and P. N. Roper, Loughborough University, United Kingdom

10:20 Desynchronization of Neural Assemblies
Stephen Coombes, Loughborough University, United Kingdom; and Gabriel J. Lord, University of Bristol, United Kingdom

10:40 A Bonhoeffer van der Pol Model for Action Potential in Excitability Changing Media
A. Rabinovich, Ben-Gurion University, Israel; I. Aviram, Beer-Sheva, Israel; N. Gulko, Ben-Gurion University, Israel; and E. Ovsyscher, Soroka Medical Center, Israel

11:00 Post-Fertilization Traveling Waves on Eggs
Gilberto Flores and Antonmaria Minzoni, National University of Mexico, Mexico; Konstantin Mischaikow, Georgia Institute of Technology; and Victor Moll, Tulane University

11:20 Additive Neural Networks and Periodic Patterns
Tomas Gedeon, Montana State University

11:40 Computational and Experimental Exploration of a Cortical Neuronal Network as a Dynamical System
David J Pinto, Joshua C. Brumberg, Daniel J. Simons, and G. Bard Ermentrout, University of Pittsburgh, Pittsburgh

10:00 AM-12:00 PM

Chair: Elbert E. N. Macau, University of Maryland, College Park
Magpie A & B - Level B

CP19
Controlling Chaos

10:00 Nonlinear Control of Remote Unstable States in a Liquid Bridge Convection Experiment
Valery Petrov, Michael F. Schatz, Kurt A. Muehlner, Stephen J. VanHook, W. D. McCormick, J. B. Swift, and Harry L. Swinney, University of Texas, Austin

10:20 Targeting from a Chaotic Scattering
Elbert E. N. Macau and Edward Ott, University of Maryland, College Park

10:40 Sustaining Chaos using Basin Boundary Saddles
Ira B. Schwartz, Naval Research Laboratory; and Ioana Triandaf, SAIC, McLean, VA

11:00 Exponentially Amplified Sampling and Reconstruction of Weak Signals Using Controlled Chaotic Orbits
Chance M. Glenn, Sr., Johns Hopkins University

11:20 Suppressed and Induced Chaos by Near Resonant Perturbation of Bifurcations
Larry Fabiny and Sandeep T. Vohra, Naval Research Laboratory

1:30 PM-2:30 PM

Chair: Charles R. Doering, University of Michigan, Ann Arbor

Ballroom I, II, III - Level B

IP7
Biomolecular Motors

Biological cells contain microscopic robotic machinery that is used for cell motility, for transport of vesicles and organelles within cells, to move protein molecules across internal membranes, to partition chromosomes at cell division, and to manufacture the entire biomolecular machinery of the cell. Unlike the macroscopic machinery of everyday experience, these molecular motors function in a regime in which Brownian motion plays an important role. Chemical energy is used to rectify the Brownian motion and hence to drive a molecular motor in a particular direction. The speaker will discuss two examples, both associated with microtubules: kinesin, which is a motor protein that "walks" along microtubules; and chromosome transport, which is driven by the depolymerization of the microtubule itself.

Charles S. Peskin
Courant Institute of Mathematical Sciences
New York University

3:00 PM-5:00 PM

Magpie A & B - Level B

MS30
Low-Frequency Variability in the Double-Gyre Circulation

The high degree of low-frequency variability characteristic of most geophysical systems is very important for long-time predictions. Such naturally occurring systems are usually exceedingly complex. However, highly simplified models of such systems also show a remarkable degree of low-frequency variability. Thus, while an understanding of low-frequency variability in oceanic and atmospheric flows is of crucial importance to understanding the climate of our planet, it is possible to address this issue in the context of a simple but prototypical oceanic flow—the problem of adiabatic double-gyre circulation. The short and noisy nature of the numerical simulations of even such highly simplified models necessitates the use of modern dynamical system tools and sophisticated spectral estimation procedures to enhance our understanding of these systems. Further, this is a necessary step to put forward phenomenological explanations of the variability. Good estimates of low-frequency variability in geophysical systems using the available short and noisy time series is a difficult problem. Traditional methods are mostly based on ideas of Fourier Transforms, etc., and their usage tends to be very restrictive for short and noisy time series. Therefore this very important aspect, with direct implications for long-time prediction, has not received the attention it deserves. The more recent usage of data-adaptive bases and filters, maximum-entropy methods, singular-spectrum analysis, etc., may be more suitable in this context.

Organizers: Balu T. Nadiga and Darryl D. Holm
Los Alamos National laboratory

3:00 Low Frequency Variability in Ocean Circulation Models Driven by Constant Forcing
Richard J. Greatbatch, Memorial University of Newfoundland, Canada

3:30 Low-Frequency Variability in the Reduced-Gravity Shallow Water Model
Balu T. Nadiga, Organizer; Len Margolin, Los Alamos National Laboratory; and Darryl D. Holm, Organizer

4:00 Low-Frequency Variability of Wind-Driven Ocean Gyres
Pavel S. Berloff and *James C. McWilliams*, University of California, Los Angeles

4:30 Mathematical and Computational Issues in the Double Gyre Model
John D. McCalpin, Silicon Graphics, Inc.

3:00 PM-5:00 PM

Ballroom I - Level B

MS31
Model Reduction, Analysis, and Control of Spatio-Temporal Dynamics Using KL Methods

Understanding the dynamics of spatio-temporal (ST) phenomena is important in many areas of research, such as turbulent flow, reaction-diffusion systems, and coupled os-

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cillators. Because ST dynamics exhibits both low and and high dimensional behavior, it is important to characterize the behavior in a practical way, since many methods from low dimensional dynamics do not carry over to ST systems. One recent methodology for understanding ST dynamics is that of Karhunen-Loeve (KL) decomposition. One of the main advantages in using KL methods is that an orthogonal basis can be constructed from measured data, and then used to project out low dimensional dynamic models. In this minisympoium, the speakers will address areas of application of KL methods to both continuous and discrete applied areas in dynamics. Projected low dimensional behavior of fluid mechanics, analysis and control of bursting in reaction-diffusion, singularly perturbed structural mechanics, and large arrays of coupled oscillators will be discussed using a KL point of view.

Organizer: Ira B. Schwartz
U.S. Naval Research Laboratory

3:00 Analysis of Extensive Chaos by the Karhunen-Loeve Decomposition and by a Hierarchy of Unstable Periodic Orbits
Henry Greenside, Duke University

3:30 Analysis and Control of Spatio-Temporal Chaos in Reaction-Diffusion Processes
Ioana Triandaf, Science Applications International Corporation

4:00 New Measures of Coherence in Disordered and Noisy Arrays of Coupled Phase Oscillators
Thomas W. Carr, Southern Methodist University; and Ira B. Schwartz, Organizer

4:30 Modeling the Dynamics of Wall Bounded Turbulence
Larry Sirovich, Brown University and Mount Sinai School of Medicine

3:00 PM-5:00 PM

Wasatch A & B - Level C

MS32

Continuum Models of Biological Macromolecules

A number of biologically important molecules are extremely large and exhibit significant behaviors on length scales much longer than the atomic. Super-coiling of DNA and deformations of alpha-helical proteins are two prime examples. Recently there has been considerable interest in simulating such molecules within the context of some form of continuum description. This minisymposium provides an opportunity for junior members from each of four different research groups in this area to present their work. Static models typically involve the study of systems of ODE with 'evolution' in arc-length, while dynamic models involve systems of PDE in 1+1 dimensions, but in both statics and dynamics mathematically unusual features, for example nonlocal terms, can arise in modelling phenomena such as contact.

Organizer: John H. Maddocks
University of Maryland, College Park

3:00 Modeling Stable Configurations of Protein-bound DNA Rings
Jennifer A. Martino and Wilma K. Olson, Rutgers University

3:30 A Combined Wormlike-Chain and Bead Model for Dynamic Simulations of Long DNA
Hongmei Jian, Alexander Vologodskii; and Tamar Schlick, New York University

4:00 Stability in Continuum Models of DNA Minicircles
Kathleen A. Rogers and Robert S. Manning, University of Maryland, College Park; and John H. Maddocks, Organizer

4:30 Stability of the Stationary States of the Elastic Rod Model Under an Applied External Force that Represent Configurations of DNA in Living Cells
Thomas Connor Bishop and John E. Hearst, University of California, Berkeley

3:00 PM-5:00 PM

Ballroom II - Level B

MS33

Periodically and Randomly Driven Dynamics in Nonlinear Optical Fibers

The equation governing pulse propagation in nonlinear optical fibers and waveguides under ideal conditions is the completely integrable nonlinear Schrödinger (NLS) equation. In more realistic situations, however, this equation can be perturbed by effects such as continuous or discrete loss and periodic gain, amplified spontaneous emission noise, periodic variations in the dispersion coefficient (also known as dispersion management), or by two-polarization field envelope interactions. In this minisymposium (and the associated contributed paper session) the relevant physical and mathematical issues, both resolved and open, will be discussed.

Organizers: J. Nathan Kutz, Princeton University; and William L. Kath, Northwestern University

3:00 Propagation of Nonsoliton Pulses in Long Optically Amplified Transmission Lines
Stephen Evangelides Jr., AT&T Research

3:30 Nonlinear Optical Phenomena in Periodic Structures
Herbert G. Winful, University of Michigan, Ann Arbor

4:00 Modelocked Fiber Laser Simulation and Modeling
J. W. Haus and G. Shaulov, Rensselaer Polytechnic Institute; and J. Theimer, Rome Laboratory RL/OCPA

4:30 The Whitham Equations for Optical Communications in NRZ Format
Yuji Kodama, Osaka University, Japan

3:00 PM-5:00 PM

Ballroom III - Level B

MS34

Topology in Dynamics

The speakers in this minisymposium will present ideas in dynamics that are primarily topological in nature especially to experimentalists and theorists interested in dynamical systems.

Organizer: James A. Yorke
University of Maryland, College Park

3:00 Crises: The Dynamics of Invariant Sets as a Parameter is Varied
James A. Yorke, Organizer; and Kathleen Alligood, George Mason University

3:30 Horseshoes and the Conley Index Spectrum
Konstantin Mischaikow, Georgia Institute of Technology

4:00 A Case Study of Topology Preserved in an Environment with Noise: Fluid Flowing Past an Array of Cylinders
Judy A. Kennedy, University of Delaware

4:30 Stable Ergodicity and Stable Accessibility
Charles C. Pugh and Mike Shub, University of California, Berkeley

3:00 PM-5:00 PM

Chair: Amitabha Bose, New Jersey Institute of Technology
Superior B - Level C

CP20

Neural and Excitable Systems II

3:00 Weakly Connected Weakly Forced Oscillatory Neural Networks
Eugene Izhikevich and Frank Hoppensteadt, Arizona State University

3:20 Dynamics of Two Mutually Coupled Slow Inhibitory Neurons
David Terman, Ohio State University; Nancy Kopell, Boston University; and *Amitabha Bose*, New Jersey Institute of Technology

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3:40 Nonequilibrium Response Spectroscopy of ION Channel Gating Kinetics
Mark M. Millonas, University of Chicago

4:00 Hodgkin-Huxley Neuronal Models
Allan R. Willms, Cornell University

4:20 Preservation and Annihilation of Colliding Pulses in a Model Excitable System
M. Argentina and P. Coullet, Institut Non-Lineaire de Nice, France; and *L. Mahadevan*, Massachusetts Institute of Technology

4:40 Monitoring Changing Dynamics with Correlation Integrals: Case Study of an Epileptic Seizure
David E. Lerner, University of Kansas

3:00 PM-5:00 PM

Chair: Peter Smereka, University of Michigan, Ann Arbor
Maybird - Level C

CP21
Synchronization II

3:00 Spontaneous Synchronization and Critical Behavior in Oscillator Chains
Jeffrey L. Rogers, Georgia Institute of Technology

3:20 Synchronization and Relaxation in Globally Coupled Oscillators
Peter Smereka, University of Michigan, Ann Arbor

3:40 Coupling Topology and Global Dynamics
Duncan J. Watts and Steven H. Strogatz, Cornell University

4:00 Synchronization of Spatio-Temporal Chaos
Mikhail M. Sushchik Jr., Nikolai F. Rulkov, and Michael M. Rabinovich, University of California, San Diego

4:20 Effect of Finite Inertia in Coupled Oscillator Systems
Hisa-Aki Tanaka, Waseda University, Tokyo

4:40 Synchronized Chaos in Spatially Extended Systems and Interhemispheric Teleconnections
Gregory S. Duane and Peter J. Webster, University of Colorado, Boulder

3:00 PM-5:00 PM

Chair: Timothy Whalen, National Institute of Standards and Technology
Superior A - Level C

CP22
Melnikov Theory

3:00 Asymptotic Expansions for Melnikov Functions for Conservative Systems
Joseph Gruendler, North Carolina A&T State University

3:20 The Melnikov Theory for Subharmonics and Their Bifurcations in Forced Oscillations
Kazuyuki Yagasaki, Gifu University, Japan

3:40 The Melnikov Vector as an Estimate for Exponentially Small Splitting of Homoclinic Manifolds
Alain Goriely, Craig Hyde, and Michael Tabor, University of Arizona

4:00 Calculating Chaotic Strength
David B. Levey and Paul D. Smith, University of Dundee, United Kingdom

4:20 Melnikov's Method for Stochastic Multi-Degree of Freedom Dynamical Systems - Theory and Applications
Timothy Whalen, National Institute of Standards and Technology

4:40 Resonance Capture in Weakly Forced Mechanical Systems
D. Dane Quinn, University of Akron

6:30 PM-7:30 PM

Ballroom I, II, III - Level B

Poster Setup

7:30 PM-9:30 PM

Ballroom I, II, III - Level B

Poster Session I

Lagrangian Formalism of Hydrodynamic Forces on Dust Particles
Abdulmuhsen H. Ali, Kuwait University, Kuwait

Modelling and Phase Analysis of Immunological Process at Primary Immune Response
Ivan Edissonov, Bulgarian Academy of Sciences, Bulgaria

Global Bifurcations in Periodically Driven Zero-Dispersion Systems
S. M. Soskin, National Ukrainian Academy of Sciences, Ukraine

Spectra of Frequency-Modulated Waves
George D. Catalano, U.S. Military Academy

Symmetry Breaking Perturbations and Strange Attractors
Anna Litvak Hinenzon and Vered Rom-Kedar, The Weizmann Institute of Science, Israel

Simulation of the Immune System on Parallel Computers
Massimo Bernaschi, IBM DSSC, Italy; Filippo Castiglione, University of Catania, Italy; and *Sauro Succi*, IAC CNR, Italy

Invariant Measure for Dynamical Distributed Parameter Systems
Zdzislaw W. Trzaska, Warsaw University of Technology, Poland

The Construction of the Analytic Periodic Solution in the Framework of the Multiple Time Scale Method
Sorinel Adrian Oprisan, "Al. I. Cuza" University, Romania

Markov Random Fields and Dynamical Systems with Memory in Pattern Generation and Recognition Processes
Sorinel Adrian Oprisan, "Al. I. Cuza" University, Romania

The Separatrix Map Approximation of Critical Motion in the 3/1 Jovian Resonance
Ivan I. Shevchenko, Russian Academy of Sciences, Russia

Application of Centre Manifold Theory to an Adaptive Control Problem
Graciela A. Gonzalez, Universidad de Buenos Aires, Argentina

Extensive Chaos and Unstable Period Orbits
Scott M. Zoldi and Henry S. Greenside, Duke University

Bifurcations in Systems of Coupled Bistable Units
Mark E. Johnston, University of Cambridge, United Kingdom

Chaotic Communications in the Presence of a Wireless Channel
Christopher Williams and Mark A. Beach, University of Bristol, United Kingdom

Forced Vibration of a Partially Delaminated Beam
Roger P. Menday and M. C. Harrison, University of Loughborough, United Kingdom; and E. R. Green, Leicester University, United Kingdom

Dynamical Features Simulated by Recurrent Neural Networks
Fernanda Botelho, University of Memphis

Inertial Functions: Definition, Existence and Stability
Kevin M. Campbell, Michael E. Davies, and Jaroslav Stark, University College London, United Kingdom

Blownout Attractors
Peter Ashwin and Philip Aston, University of Surrey, United Kingdom; *Matthew Nicol*, University of Manchester Institute of Science and Technology, United Kingdom

Forced Symmetry-Breaking in Coupled Oscillator Networks
Carlo Laing, University of Cambridge, United Kingdom

The Method of Melnikov for Perturbations of Multi-Degree-of-Freedom Hamiltonian Systems
Kazuyuki Yagasaki, Gifu University, Japan

Reconstruction and Prediction of Stochastic Dynamical Systems Using Topology Preserving Networks
Markus Anderle and *Sabino Gadaleta*, Colorado State University

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Computing the Measure of Nonattracting Chaotic Sets
Joeri Jacobs, Edward Ott, and Celso Grebogi, University of Maryland, College Park

Information Content of Cellular Automaton Traffic Simulations
Brian W. Bush, Los Alamos National Laboratory

Control of Differentially Flat Robotic Systems in the Presence of Uncertainty
Kristin Glass, Richard Colbaugh, and Tuna Saracoglu, New Mexico State University, Las Cruces

Control of Uncertain Mechanical Systems Using Reduction and Adaptation
Richard Colbaugh, Ernest Barany, Gil Gallegos, and Mauro Trabatti, New Mexico State University

Chemical Mixing Using a Chaotic Flow
Xianzhu Tang, College of William and Mary; and Allen H. Boozer, Columbia University

Symbolic Time Series Analysis of Continuous Dynamical Systems
Eugene R. Tracy, X.-Z. Tang, Reggie Brown, and S. Burton, College of William and Mary

Signal Compression and Information Retrieval via Symbolization
Xianzhu Tang and Eugene R. Tracy, College of William and Mary

The Magnetic Pendulum
Francisco Cervantes de la Torre, J. L. Fernandez Chapou, UAM-AZCAPOTZALCO, CBI., Mexico

Newton-Picard Methods for Robust Continuation and Bifurcation Analysis of Periodic Solutions of Infinite-Dimensional Dynamical Systems with Low-Dimensional Dynamics
Koen Engelborghs, Kurt Lust, and Dirk Roose, Katholieke Universite Leuven, Belgium

Scale-Sensitive Linear Analysis of Granivorous Rodent Population Dynamics
Nikkala A. Pack, North Carolina State University; and Brian A. Maurer, Brigham Young University

Hamiltonian Moment Reduction for Describing Vortices in Shear Flow
S. Meacham, Florida State University; *P. J. Morrison*, University of Texas, Austin; and G. Flierl, Massachusetts Institute of Technology

Controlling On-Off Intermittent Dynamics
Yoshihiko Nagai, Xuan-Dong Hua, and Ying-Cheng Lai, University of Kansas

Dynamics of Interacting Modes in EEG-Datasets
Christian Uhl, Max-Planck-Institute of Cognitive Neuroscience, Germany; Raul Kompass, University of Leipzig, Germany

Enhancement of Stochastic Resonance of FitzHugh-Nagumo Neuronal Model Driven by 1/f Noise
Daichi Nozaki and Yoshiharu Yamamoto, University of Tokyo, Japan

Chaotic Scattering in Micro Lasing Cavities
Tolga Yalcinkaya and Ying-Cheng Lai, University of Kansas

Intermingled Basins of Attraction: Uncomputability in a Simple Physical System
John C. Sommerer, Johns Hopkins University; and Edward Ott, University of Maryland, College Park

A Model for Flows with Separation and the Circular Hydraulic Jump
Shinya Watanabe, Vachtang Putkaradze, Tomas Bohr, Adam E. Hansen, Anders Haaning, and Clive Ellegaard, Niels Bohr Insitute, Denmark

A Nonlinear Model to Classify Dynamic Time Series
Karin Schmidt, Friedrich Schiller University Jena, Germany; and Hazel H. Szeto, Cornell University Medical College

Synchronization of Structures by a Small Number of Couplings
Ya. I. Molkov, M. M. Sushchik, and A. V. Yulin, Russian Academy of Science, Russia

Clusters in Globally Coupled Assemblies of Bistable Elements
A. V. Yulin and M. M. Sushchik, Russian Academy of Science, Russia

Symmetry-Breaking Parametric Instabilities in Circular Josephson Junction Arrays
John J. Derwent and Mary Silber, Northwestern University

Numerical Evidence of Standing and Breathing Solutions for the Oregonator with Equal Diffusivities
Jack Dockery and Richard J. Field, Montana State University

Using Linear Integro-Difference Equations to Emulate Solutions to a Temporally Stiff System of PDE's
Tyler K. McMillen, Utah State University

Ionic Diffusion Within the Confined Extracellular Space of Glomeruli
Anita Rado, Alwyn Scott, and Leslie Tolbert, University of Arizona

Dynamical Behavior of a Model for Hormonal Regulation During the Menstrual Cycle in Women
Paul M. Schlosser, Chemical Industry Institute of Toxicology, Research Triangle Park; and *James F. Selgrade*, North Carolina State University

Scaling of Travelling Waves Produced from Electrostatic Instabilities
Anandhan Jayaraman and John David Crawford, University of Pittsburgh, Pittsburgh

Enhancing Stochastic Resonance in a Single Unit
Carson C. Chow, Thomas T. Imhoff, and James J. Collins, Boston University

Long-Time Term Behaviour of Density Oscillator
Carlos A. Vargas and Alejandro Ramirez-Rojas, Universidad Autonoma Metropolitana Azcapotzalco, Mexico

Using Spatial Disorder to Synchronize Dynamical Systems
Yuri Braiman, Emory University; and John Lindner, The College of Wooster

Continuum Limits of Convective-Diffusive Lattice Boltzmann Methods
Cecilia Fosser and C. David Levermore, University of Arizona

Numerical Analysis of Phase Synchronization of Coupled Model Neurons
Alexander K. Kozlov, Russian Academy of Sciences, Russia

Characterization of Noise in Electrotelluric Time Series
Alejandro Ramirez-Rojas, Francisco Cervantes-de la Torre, and Carlos G. Pavia-Miller, Universidad Autonoma Metropolitana Azcapotzalco, Mexico; Fernando Angulo-Brown, Escuela Superior de Fisica y Matematicas, I.P.N., Mexico

Taking the Temperature of an Epileptic Seizure
David E. Lerner, University of Kansas

Dimension and KLD Correlation Lengths in a Two-Dimensional Excitable Medium
Matthew C. Strain and Henry Greenside, Duke University

Nonlinear Pattern Dynamics in Two-Dimensional Josephson-Junction Networks
Werner Guettinger and *Joerg Oppenlaender*, University of Tuebingen, Germany

Dynamics in the Undergraduate Mathematics Program
Richard F. Melka, University of Pittsburgh, Bradford

Two Meaningful Alternative Representations of Dynamic Behaviour
G. Arthur Mihram, Princeton, NJ; and *Danielle Mihram*, University of Southern California

Trapping and Wiggling: Elastohydrodynamics of Driven Microfilaments
Chris H. Wiggins, Princeton University, Daniel X. Riveline and Albrecht Ott, Institut Curie, France; and Raymond E. Goldstein, University of Arizona

Bifurcations and Edge Oscillations in an Inhomogeneous Reaction-Diffusion System
Jonathan E. Rubin, Ohio State University, Columbus

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Breaking the Symmetry of an Attractor Merging Crisis
Miguel A. F. Sanjuan, Universidad Politecnica de Madrid, Spain

Effects of Anisotropy on Nonlinear Evolution of Morphological Instability in Directional Solidification
Alexander Golovin and Stephen Davis, Northwestern University

Integro-Differential Model for Orientational Distribution of F-Actin in Cells
Alex Mogilner, University of California, Davis; Edith Geigant, University of Bonn, Germany; and Karina Ladizhansky, Weizmann Institute of Science, Israel

Canard Explosion and Bistability in the Belousov-Zhabotinsky Reaction
Jon-Paul Voroney, University of Guelph, Canada

Wednesday, May 21

8:30 AM-9:30 AM

Chair: Boris L. Altshuler, NEC Research, Inc.
Ballroom I, II, III - Level B

IP8
Small Electronics and Quantum Chaos

The transport properties of electronic devices below the few-micrometer scale show signatures of quantum interference and quantum confinement when the devices are cooled near absolute zero. This talk will summarize recent experiments measuring random (but perfectly repeatable) fluctuations in conductance of these structures - known as quantum dots - and the connection between the universal statistical properties of these fluctuations and the universal spectral statistics of random matrix theory and quantum manifestations of chaos.

There has been great progress in this field in the last few years, and the behavior of quantum-coherent electrons is now well in hand, with good agreement between theory and experiment. This success story applies when the unavoidable coupling of electrons to the environment and each other is small. The great outstanding problems in the field concern the the inclusion of interactions and decoherence. Some of these issues - somewhat less of a success story - will also be discussed.

Charles M. Marcus
Department of Physics, Stanford University

10:00 AM-12:00 PM

Magpie A & B - Level B

MS35
Molecular Motors

The advent of new technologies for measuring forces and displacements at the molecular scale has led to a resurgence in mathematical modeling of molecular motors. These protein devices are thousands of times smaller than the smallest 'nanotechnology' has yet achieved, yet they power virtually all aspects of the living cell. This minisymposium will present several case studies in how these motors are modeled and how the models compare to experimental data. The talks will give an overview of the mathematical techniques currently employed to model protein motors. Some familiarity with cell biology would be helpful, but hopefully not necessary.

Organizer: George F. Oster
University of California, Berkeley

10:00 Mathematical Models of Stochastic Ratchets
Charles R. Doering, University of Michigan, Ann Arbor

10:30 Cell Motions Driven by Actin Polymerization
George F. Oster, Organizer

11:00 The Bacterial Flagellar Motor: A New Mechanism for Energy Transduction
Timothy C. Elston, Los Alamos National Laboratory; and George Oster, Organizer

11:30 Nano-Motors: Rotary Enzyme Complexes
Ronald F. Fox, Georgia Institute of Technology

10:00 AM-12:00 PM

Ballroom I - Level B

MS36
Transport in Hamiltonian Systems

How does a blob of initial conditions evolve under a Hamiltonian flow? How do we characterize such a motion, composed of regular and chaotic components? These questions arise in diverse fields such as celestial mechanics, mechanical systems, Lagrangian advection in fluids and geophysics, and particle confinement in plasma. Here, fundamental mechanisms governing transport and their applications will be discussed; the role of self-similarities, of partial barriers and of degeneracies in two, three, and four dimensional maps and flows will be revealed. Finally, the implications of such theories on observable transport in fluids will be discussed.

Organizer: Vered Rom-Kedar
Weizmann Institute of Science, Israel

10:00 Scaling Properties of Distributions of Exit Time and Poincaré Recurrences
G. M. Zaslavsky, Courant Institute of Mathematical Sciences, New York University

10:30 Transport in Quadratic Volume Preserving Maps
James D. Meiss, University of Colorado, Boulder

11:00 Lagrangian and Eulerian Transport: Are They Related?
George Haller, Brown University

11:30 Degenaracies, Instabilities and Transport
Vered Rom-Kedar, Organizer

CONFERENCE PROGRAM

Wednesday, May 21

10:00 AM-12:00 PM

Ballroom II - Level B

MS37

Fundamental Nonlinear Dynamics of Diode Lasers

Diode lasers are widely used in applications, such as consumer products as CD players and barcode scanners, and optical telecommunication. Many important aspects of their behavior are due to nonlinear effects. We concentrate on the two important mechanisms of optical injection and delayed optical feedback, both of which cause effects that are fundamentally nonlinear in nature. Different models are studied, notably by using bifurcation theory and numerical simulations, in the attempt to understand and control the dynamics. The models need to be checked, which leads to an intriguing interplay between experiments and theory. We want to communicate recent results on nonlinear dynamics of diode lasers and how they have been obtained. The intended audience includes researchers on lasers as well as applied mathematicians interested in concrete problems. As the methods are generally not unique to the field of lasers, we also hope for interest from other applied fields. The purpose is to exchange ideas and hopefully stimulate further research.

Organizer: Bernd Krauskopf
Vrije Universiteit, The Netherlands

10:00 Bifurcations to Periodic Solutions in Diode Lasers Subject to Injection
A. Gavrielides and V. Kovanis, Phillips Laboratory; T. Erneux and G. Lythe, Université Libre de Bruxelles, Belgium

10:30 Bifurcation Analysis of a Phase-Amplitude Model of an Injected Diode Laser
Bernd Krauskopf, Organizer; Daan Lenstra and Wim van der Graaf, Vrije Universiteit, The Netherlands

11:00 Control of Optical Turbulence in High Brightness Semiconductor Lasers
Jerome V. Moloney and *David Hochheiser*, University of Arizona

11:30 Controlling Temporal and Spatio-Temporal Dynamics in Semiconductor Lasers by Delayed Optical Feedback
Markus Muenkel, University of Technology, Darmstadt, Germany; Christian Simmendinger and Ortwin Hess, Institute of Technical Physics, DLR, Germany

10:00 AM-12:00 PM

Ballroom III - Level B

MS38

Applications of Synchronized Chaos and Hyperchaos

Recently interest has piqued in synchronized, chaotic systems, primarily because they represent a possible use of chaos in a communications setting. Advances in the area have led to the ability to synchronize hyperchaotic systems, which allow the transmission of more complicated waveforms while retaining synchronization. We present here several of these recent advances including multiplexing of chaos, techniques for synchronizing hyperchaos and hyperchaotic circuits, and generalized versions of synchronization. The purpose is to stimulate a wide audience interested in both the theoretical issues of chaos synchronization and the practical uses for such behavior. Interested fields include dynamical systems analysts, electrical engineers, physicists, and communications.

Organizer: Louis M. Pecora
Naval Research Laboratory

10:00 Synchronizing Hyperchaos for Communications
Mingzhou Ding, Florida Atlantic University

10:30 Synchronizing Hyperchaotic Volume-Preserving Map Circuits
Thomas L. Carroll, Naval Research Laboratory

11:00 Multiplexing Chaotic Signals Using Synchronization
Lev S. Tsimring, N. F. Rulkov, M. M. Sushchik, and H. D. I. Abarbanel, University of California, San Diego

11:30 On Generalized Synchronization
Ljupco Kocarev, St. Cyril and Methodius University, Republic of Macedonia

(This session will run until 1:00 PM)

10:00 AM-12:00 PM

Wasatch A & B - Level B

MS39

Spatially Discrete Dynamical Systems - Theory and Applications

Spatially discrete dynamical systems are either infinite-dimensional systems which possess a discrete spatial structure, generally modeled on a regular lattice, or finite dimensional systems which could be cellular neural networks (CNN) or cellular automata. The time variable can be either discrete or continuous. Such systems arise as models in a wide variety of applications, including image processing, material science, and biology. They moreover represent a new direction in mathematics, giving rise to challenging mathematical problems of pattern formation, spatial chaos, traveling waves, and synchronization. The talks in mathematical theory and applications on similar problems will clearly demonstrate the continuity between applications, scientific computing, and mathematics.

Organizers: John Mallet-Paret, Brown University; and Shui-Nee Chow, Georgia Institute of Technology

10:00 Transition from Slow Motion to Pinning in Lattice Equations
Christopher P. Grant, Brigham Young University

10:30 Modeling Biological Systems by Means of Nonlinear Electronic Circuits
Alberto P. Munuzuri and L. O. Chua, University of California, Berkeley; and V. Perez-Munuzuri, University of Santiago de Compostela, Spain

11:00 Traveling Waves in Lattice Dynamical Systems
Wenxian Shen, Auburn University

11:30 Information Propagation, Pattern Formation and Reaction-Diffusion with Cellular Neural Networks
Patrick Thiran, Swiss Federal Institute of Technology, Switzerland; and Gianluca Setti, University of Bologna, Italy

12:00 Traveling Waves, Equilibria, and the Computation of Spatial Entropy for Spatially Discrete-Reaction Diffusion Equations
John W. Cahn, National Institute of Standards and Technology; Shui-Nee Chow, Georgia Institute of Technology; John Mallet-Paret, Organizer; and *Erik S. Van Vleck*, Colorado School of Mines

10:00 AM-12:00 PM

Chair: William R. Derrick, University of Montana
Superior A - Level C

CP23

Bursting and Biochemical Oscillations

10:00 Delaying the Transition to the Active Phase in Bursting Oscillators
Thomas W. Carr, Southern Methodist University; and Victoria Booth, New Jersey Institute of Technology

10:20 Slow Subsystem Bifurcations in Systems Exhibiting Bursting
Mark Pernarowski, Montana State University

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10:40 Effect of Weak Coupling on Oscillations in Bursting Systems
Gerda de Vries and Arthur Sherman, National Institutes of Health

11:00 Interpretation of Chaos in the Belousov-Zhabotinsky Reaction
Richard J. Field, University of Montana

11:20 Bifurcations in One Model of the Bray-Liebhafsky Oscillations
William R. Derrick and Leonid V. Kalachev, University of Montana

11:40 Phase-Locking and Chaos in Forced Excitable Systems
Min Xie and *Hans G. Othmer*, University of Utah

12:00 Synchronous Bursting in Coupled Neurons
M. M. Susheik, Ya. I. Molkov, and M. I. Rabinovich, Russian Academy of Sciences, Russia

10:00 AM-12:00 PM

Chair: Rebecca Hoyle, University of Cambridge, United Kingdom
Superior B - Level C

CP24

Waves and Ginzburg-Landau Equations

10:00 Convective and Absolute Instability in Finite Containers
Steven M. Tobias, University of Colorado, Boulder; Edgar Knobloch, University of California, Berkeley; and Michael R. E. Proctor, University of Cambridge, United Kingdom

10:20 Fronts Between Rolls of Different Wavenumbers in the Presence of Broken Reflection Symmetry
Rebecca Hoyle, University of Cambridge, United Kingdom

10:40 Dynamics of a 2-Dimensional Complex Ginzburg-Landau Equation with Chiral Symmetry Breaking
Keeyeol Nam, Michael Gabbay, Parvez N. Guzdar, and Edward Ott, University of Maryland, College Park

11:00 Coupled Oscillators in Fluid Mechanics: Wakes Behind Rows of Cylinders
Patrice Le Gal, Jean-Francis Ravoux, and Isabelle Peschard, Université d'Aix-Marseille I & II-CNRS, France

11:20 Vortex Dynamics in Dissipative Systems
Elsebeth Schroder, Niels Bohr Institute, Denmark; and Ola Tornkvist, NASA/Fermilab Astrophysics Center

11:40 Noise Sensitivity and Boundary Effects in Travelling Wave Instabilities
Michael R. E. Proctor, University of Cambridge, United Kingdom; Edgar Knobloch, University of California, Berkeley; and Steven M. Tobias, University of Colorado, Boulder

12:00 Defects and Domain Walls in the 2d Complex Ginzburg-Landau Equation
Greg Huber, University of Chicago; Tomas Bohr, Niels Bohr Institute, Denmark; and Edward Ott, University of Maryland, College Park

10:00 AM-12:00 PM

Chair: Bruce J. Gluckman, Naval Surface Warfare Center and The Children's Research Institute of George Washington University
Maybird - Level C

CP25

Stochastic Resonance

10:00 Coherence Resonance in a Noise-Driven Excitable System
Arkady Pikovsky and *Jürgen Kurths*, Universität Potsdam, Germany

10:20 Stochastic Resonance in a Neuronal Network from Mammalian Brain
Bruce J. Gluckman, Naval Surface Warfare Center and The Children's Research Institute of George Washington University

10:40 Spatio-Temporal Stochastic Resonance in a System of Coupled Diode Resonators
Markus Locher, G. A. Johnson, and E. R. Hunt, Ohio University; and F. Marchesoni, University of Illinois, Urbana

11:00 Spatio-Temporal Stochastic Resonance of a Kink Motion in an Inhomogeneous phi 4 Model
Igor Dikshtein, Russian Academy of Sciences, Russia; and *Alexander Neiman*, Saratov State University, Russia

11:20 Noise-Enhanced Information Transmission in a Network of Globally Coupled Oscillators
Paul Gailey, Oak Ridge National Laboratory; Thomas Imhoff, Carson Chow, and James J. Collins, Boston University

11:40 Spatio-Temporal Stochastic Resonance in Coupled Circuits
Gregg A. Johnson, Naval Research Laboratory; M. Locher and E. R. Hunt, Ohio University, Athens

1:30 PM-2:30 PM

Chair: Jerrold E. Marsden, California Institute of Technology
Ballroom I, II, III - Level B

IP9

Nonlinear Control of Lagrangian Systems

Recent advances in geometric mechanics, motivated in large part by applications in control theory, have introduced new tools for understanding and utilizing the structure present in mechanical systems. In particular, the use of geometric methods for analyzing Lagrangian systems with both symmetries and nonholonomic constraints has led to a unified formulation of the dynamics that has important implications for a wide class of mechanical control systems. In this talk, the speaker will survey recent results in this area, focusing on the relationships between geometric phases, controllability, and curvature, and the role of trajectory generation and tracking in nonlinear controller synthesis. An important class of examples are differentially flat systems, for which the trajectory generation problem is conceptually simple and computationally tractable. Examples will be drawn from robotic locomotion, flight control systems, and other areas, including videotape of experimental results performed at Caltech.

Richard M. Murray
California Institute of Technology

3:00 PM-5:00 PM

Ballroom I - Level B

MS40

Periodic Orbits in Chaotic Systems

The role of periodic orbits in chaotic systems is well known to be of fundamental theoretical and practical importance. For example, chaotic behavior is often undesirable, and if the dynamics are low dimensional, it may be possible to replace chaos with stable periodic behavior. This minisymposium addresses recent theoretical results that are of importance to practical situations. In particular, we address the role of numerical simulations in identifying periodic orbits, the theoretical advantages to stabilizing low-periodic trajectories via feedback control, and the fundamental problem of the occurrence of stable periodicity in high dimensional chaotic systems.

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Organizers: Ernest Barreto and Edward Ott
University of Maryland, College Park

3:00 Optimal Periodic Orbits of Chaotic Systems: Control and Bifurcations
Edward Ott, Organizer; and *Brian R. Hunt*, University of Maryland, College Park

3:30 From High Dimensional Chaos to Stable Periodic Orbits: the Structure of Parameter Space
Ernest Barreto, Organizer; Brian R. Hunt, Celso Grebogi, and James A. Yorke, University of Maryland, College Park

4:00 Unstable Dimension Variability: A Source of Nonhyperbolicity in Chaotic Systems
Eric J. Kostelich, Arizona State University; Ittai Kan, George Mason University; Celso Grebogi, University of Maryland, College Park; Edward Ott, Organizer; and James A. Yorke, University of Maryland, College Park

4:30 Periodic Shadowing
Huseyin Kocak, University of Miami

3:00 PM-5:00 PM

Ballroom II - Level B

MS41

Applications of the Geometric Phase

This minisymposium will focus on recent and ongoing developments concerning the 'geometric', or 'Hannay-Berry' phase. The original setting in the pioneering paper by Berry (1984) was the adiabatic theorem from quantum mechanics dealing with a system coupled to a slowly changing environment. If the Hamiltonian varies adiabatically, then after a cyclic evolution of the environment parameters, the eigenstate returns to its original form, but with a geometric phase factor associated with it. Since this paper appeared, there has been a flood of ongoing work on both classical and quantum analogues of this phase factor and this minisymposium is meant to give a snapshot of current activity in this area.

Organizers: Jerrold E. Marsden, California Institute of Technology; and Paul K. Newton, University of Southern California

3:00 Geometric Phases and the Stabilization of Balance Systems
Jerrold E. Marsden, Organizer; Anthony Bloch, University of Michigan, Ann Arbor; Gloria Sanchez, University of Merida, Venezuela; and Naomi Leonard, Princeton University

3:30 The Phase for the Spatial Three-Body Problem
Richard Montgomery, University of California, Santa Cruz

4:00 Vortex Dynamics and the Geometric Phase
Paul K. Newton, Organizer

4:30 Coriolis Forces as an SO(3) Gauge Field: Applications to Molecular Dynamics
Robert G. Littlejohn, University of California, Berkeley

3:00 PM-5:00 PM

Ballroom III - Level B

MS42

Dynamical and Statistical Modeling of Biological Systems

Due to its intrinsic nonequilibrium nature and complexity, biological systems have become an exciting field for applying dynamical system and statistical methods to discover its underlying principles. The main theme of this minisymposium is to understand large-scale collective behavior from simple microscopic rules. The biological systems covered in this session range from RNA mutation, DNA sequence matching, protein folding to flocking dynamics. Simple microscopic rules based on experiment are used in modeling these biological systems. Continuum models can also be constructed for some cases in a coarse-grained level and analytical insight is often gained by comparing the biological systems to well studied physical systems.

Organizer: Yuhai Tu
IBM T. J. Watson Research Center

3:00 RNA Virus Evolution: Fluctuation-Driven Motion on a Smooth Landscape
Herbert Levine, Lev Tsimring, and Douglas Ridgway, University of California, San Diego; and David Kessler, Bar-Ilan University, Israel

3:30 Why Do Proteins Look Like Proteins?
Hao Li, *Chao Tang*, and Ned Wingreen, NEC Research Institute; and Robert Helling, University of Hamburg, Germany

4:00 DNA Sequence Matching and Nonequilibrium Dynamics with Multiplicative Noise
Terence Hwa and Miguel A. Munoz, University of California, San Diego; Dirk Drasdo and Michael Lassig, Max Planck Institute, Germany

4:30 Dynamics of Flocking: How Birds Fly Together
Yuhai Tu, Organizer; and John Toner, University of Oregon

3:00 PM-5:00 PM

Magpie A & B - Level B

MS43

Quantum Chaos and Mesoscopic Physics

This minisymposium concerns the universal properties of quantum mechanical systems which are chaotic in their classical limit. The speakers will discuss both open (scattering) and isolated systems, with an emphasis on the connection between quantum chaos and mesoscopic fluctuation phenomena seen in micron-scale electronic structures.

Organizer: Charles M. Marcus
Stanford University

3:00 Quantum Transport Through Micro-structures: Signatures of Chaos
Harold U. Baranger, AT&T Bell Laboratories, Lucent Technologies

3:30 Experiments in Quantum Chaos: Mesoscopic Fluctuations in Quantum Dots
Charles M. Marcus, Organizer

4:00 Chaotic Dynamics and Quantum Level Statistics
Jonathan P. Keating, University of Bristol, United Kingdom

4:30 Chaos, Quantum Mechanics, and Universality
Boris L. Altshuler, NEC Research, Inc.

3:00 PM-5:00 PM

Chair: Jack Dockery, Montana State University
Wasatch A & B - Level C

CP26

Reaction-Diffusion Equations

3:00 Wave Propagation and its Failure in a Discrete Reaction-Diffusion Equation
Paul C. Bressloff, Loughborough University, United Kingdom

3:20 Spatial Patterns and Dynamics in Filtration Combustion
Daniel A. Schult, Colgate University

3:40 The Evolution of Slow Dispersal Rates: A Reaction Diffusion System
Jack Dockery, Montana State University; Vivian Hutson, Sheffield University, United Kingdom; Konstantin Mischaikow, Georgia Institue of Technology; and Mark Pernarowski, Montana State University

4:00 Numerical Study of Bifurcation of Traveling Wave Solutions in a Reactionn-Diffusion System
Mark Friedman, University of Alabama, Huntsville

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4:20 **Transition to an Effective Medium and Traveling Waves in Heterogeneous Reaction-Diffusion Systems**
M. Bar and M. Bode, Max-Planck-Institut fur Physik Komplexer Systeme, Germany; A. K. Bangia and *Y. Kevrekidis*, Princeton University

4:40 **Rhombs, Supersquares, and Pattern Competition in Reaction-Diffusion Systems**
Stephen L. Judd and Mary Silber, Northwestern University

3:00 PM-5:00 PM

Chair: David Peak, Utah State University
Maybird - Level C

CP27
Spatio-Temporal Chaos

3:00 **Strange Attractors of the KdV-KS Equation: Spatio-Temporal Order and Chaos in 3D Film Flows**
Alexander L. Frenkel and K. Indireshkumar, University of Alabama, Tuscaloosa

3:20 **Reduction of Complexity and Control of Spatio-Temporal Chaos through Archetypes**
David Peak, Emily Stone, and Adele Cutler, Utah State University

3:40 **Spatially Coherent States in Long Range Coupled Maps**
Sridhar Raghavachari and James A. Glazier, University of Notre Dame

4:00 **Detecting and Extracting Messages from Chaotic Communications using Nonlinear Dynamic Forecasting**
Kevin M. Short, University of New Hampshire

4:20 **Local Dynamics and Spatio-Temporal Complexity**
Ralf W. Wittenberg and Philip Holmes, Princeton University

4:40 **Stability Analysis of Reaction-Diffusion Waves Near Transitions to Spatio-Temporal Chaos**
Markus Bar, Max-Planck-Institut fur Physik Komplexer Systeme, Germany; Anil K. Bangia and Yannis Kevrekidis, Princeton University

3:00 PM-5:00 PM

Chair: Robert L. Warnock, Stanford University
Superior A - Level C

CP28
Numerical Methods

3:00 **Reliable Numerical Detection of Chaotic Behaviour in Hamiltonian Systems**
Govindan Rangarajan, Indian Institute of Science, India

3:20 **The Dynamics of Variable Time-Stepping ODE Solvers**
Harbir Lamba and Andrew Stuart, Stanford University

3:40 **Multiple-Shooting Newton-Picard Methods for Computing Periodic Solutions of Large-Scale Dynamical Systems with Low-Dimensional Dynamics**
Kurt Lust, Koen Engelborghs, and Dirk Roose, Katholieke Universite Leuven, Belgium

4:00 **Convergence of a Fourier-Spline Representation of the Poincaré Map Generator**
Robert L. Warnock, Stanford University; and James A. Ellison, University of New Mexico

4:20 **Computation of Stability Basin for Large Close-to-Hamiltonian Nonlinear Systems**
Leonid Reznikov and *Mark A. Pinsky*, University of Nevada, Reno

3:00 PM-5:00 PM

Chair: Robert W. Ghrist, University of Texas, Austin
Superior B - Level C

CP29
Fluids II

3:00 **Granular Glasses and Fluctuational Hydrodynamics**
Sergei E. Esipov, James Franck Institute and University of Chicago; *Clara Saluena*, Universitat de Barcelona, Spain, James Franck Institute and University of Chicago, and Thorsten Poschel, Humboldt-Universität zu Berlin, Germany

3:20 **Continuous Avalanche Mixing of Granular Solids in a Rotating Drum**
Barry A. Peratt, Winona State University; and James A. Yorke, University of Maryland, College Park

3:40 **Beltrami Flows and Contact Geometry**
Robert W. Ghrist and John B. Etnyre, University of Texas, Austin

4:00 **Homogenization of the Navier-Stokes Equation for Oscillatory Fluids**
Björn Birnir, University of California, Santa Barbara

4:20 **The Temporal Dynamics of the Ocean Circulation**
Steve Meacham, Florida State University; and Pavel Berloff, University of California, Los Angeles

4:40 **The Transition to Chaos for an Array of External Driven Vortices**
Fred Feudel, Universität Potsdam, Germany; and Parvez Guzdar, University of Maryland, College Park

6:30 PM-7:30 PM

Ballroom I, II, III - Level B

Poster Setup

7:30 PM-9:30 PM

Ballroom I, II, III - Level B

Poster Session II

On the Solution to Nonlinear Thermal Ignition Problem for Condensed Media with Phase Transition with the Help of the "Geometrical-Optical" Asymptotic Method
G. A. Nesenenko, Bauman State Technical University, Russia

Nonlinear Dynamics of Discrete Ecosystem Models Subject to Periodic Forcing
Danny Summers, Justin G. Cranford, and Brian P. Healey, Memorial University of Newfoundland, Canada

The Geometric Phase in a Point Vortex Flow in a Circle
B. N. Shashikanth and P. K. Newton, University of Southern California

Classification of Nonlinear Time Series Using Cluster Analysis
Thomas Schreiber, University of Wuppertal, Germany

Application of the Theory of Optimal Control of Distributed Media to Nonlinear Optical Fiber
Vladimir Y. Khasilev, University of Rostov, Russia

Dynamical Precursor of Black Hole Formation Numerical Simulation
Bruce N. Miller and V. Paige Youngkins, Texas Christian University

Finitely Representable Set-Valued Maps and Computation of the Conley Index
Tomasz Kaczynski, Université de Sherbrooke, Canada

On a Certain Class of Zero-Sum Discrete-Time Stochastic Games
D. Leao Pinto, Jr., Universidade Estadual de Campinas, UNICAMP, Brazil; Marcelo Dutra Fragoso, National Laboratory for Scientific Computing, LNCC -CNPq, Brazil; and Joao Bosco Ribeiro do Val, Universidade Estadual de Campinas, UNICAMP, Brazil

Sudden Changes of Invariant Chaotic Sets in Planar Dynamical Systems
Carl Robert, University of Maryland, College Park; Kathleen T. Alligood, George Mason University; Edward Ott and James A. Yorke, University of Maryland, College Park

Manifold Reduction and Flow Reconstruction Using Karhunen-Loeve Transformations and Neural Reconstruction
Douglas R. Hundley, Colorado State University

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Influence of Measurement Desynchronization on Dynamics of Ship Motion Control System
Vladimir G. Borisov, Institute of Control Sciences, Russia; *Fedor N. Grigor'yev* and Nikolay A. Kuznetsov, Institute for Information Transmission Problems, Russia; and Pavel I. Kitsul, Mankato State University

When Can a Dynamical System Represent an Irreversible Process?
R. M. Kiehn, University of Houston

Multi-Parameter Bifurcation Analysis in Nonlinear Control Systems
Barry R. Haynes, Mark P. Davison, The University of Leeds, United Kingdom

Can Markoff Chain Theory Determine a Signals Origin: Chaos or Random?
Charles R. Tolle, David Peak, and Robert Gunderson, Utah State University

Scaling Behavior of Transition to Chaos in Quasiperiodically Driven Dynamical Systems
Ying-Cheng Lai, University of Kansas; Ulrike Feudel, Max-Planck Arbeitsgruppe "Nichtlineare Dynamik", Universität Potsdam, Germany; and Celso Grebogi, University of Maryland, College Park

Noise-Induced Riddling in Chaotic Systems
Ying-Cheng Lai, University of Kansas; and Celso Grebogi, University of Maryland, College Park

Discontinuous Bifurcations and Crises in a DC/DC Buck Converter
Mario di Bernardo, University of Bristol, United Kingdom; Chris J. Budd, University of Bath, United Kingdom; and Alan R Champneys, University of Bristol, United Kingdom

The Invariant Manifolds and Solar System Dyanmics
Martin W. Lo and Shane D. Ross, California Institute of Technology

Lyapunov Transforms and Invariant Stability Exponents
William E. Wiesel, Air Force Institute of Technology/ENY

Dichotomies and Numerics of Stiff Problems
B. Katzengruber and P. Szmolyan, Technische Universität Wien, Austria

Computation of Invariant Tori Near L_1 in the Earth-Sun System
Gerard Gomez, Universitat de Barcelona, Spain; *Angel Jorba* and Josep Masdemont, Universitat Politecnica de Catalunya, Spain

Lyapunov Exponents from the Dynamics of Classical and Quantal Distributions
Arjendu K. Pattanayak and Paul Brumer, University of Toronto, Canada

Deterministic Chaos and Analysis of Singularities
Alexander Tovbis, University of Central Florida

Chaos and Crises in More Than Two Dimensions
Silvina Ponce Dawson and Pablo Moresco, University of Buenos Aires, Argentina

Steps Toward the Long-Term Simulation of Turbulent Flows through Higher-Order Incremental Unknowns/Hierarchical Basis
Salvador Garcia, Universidad de Talca, Chile

Stick-Slip Dynamics and Friction in an Array of Coupled Nonlinear Oscillators
H. G. E Hentschel, Yuri Braiman, and Fereydoon Family, Emory University

A Hilbert Space Framework for the Analysis of Bifurcations in Control
Aubrey B. Poore and *Timothy J. Trenary*, Colorado State University

Causal Bifurcation Sequences in Systems Containing Strong Periodic Forcing
E. A. D. Foster, Memorial University of Newfoundland, Canada

Optimal Dynamic Nonlinear Pricing and Capacity Planning
Susan Y. Chao and Samuel Chiu, University of California, Berkeley and Stanford University

Stacked Lagrange Tops: Analysis of Multi-Component Systems
Debra Lewis, University of California, Santa Cruz

Recurrent Propagation of a Wave Front in an Excitable Medium
Yue-Xian Li, University of California, Davis

Instabilities of Hexagon Patterns in a Model for Rotating Convection
Filip Sain and Hermann Riecke, Northwestern University

Use of Parametric Excitation for Unstable Fixed Point Detection and Capture
Peter M. Van Wirt, United States Air Force, Air Force Institute of Technology and Utah State University; Robert Gunderson and David Peak, Utah State University

Dynamics of the Ginzburg-Landau Equations of Superconductivity
Hans G. Kaper, Argonne National Laboratory; Peter Takac, Universität Rostock, Germany

Global Bifurcations in a Reaction-Difussion Model Leading to Spatio-Temporal Chaos
Martin Zimmermann and Sascha Firle, Uppsala University, Sweden; Mario Natiello, Royal Institute of Technology, Sweden; Michael Hildebrand and Markus Eiswirth, Max-Planck Gesellschaft, Berlin, Germany; Markus Bar, Max-Planck-Institut fur Physik Komplexer Systeme, Germany; A. K. Bangia and Yannis G. Kevrekidis, Princeton University

Resonance Zones for Henon Maps
Robert Easton, University of Colorado, Boulder

Using Manifolds to Generate Trajectories for Libration Point Missions
Kathleen C. Howell, Purdue University, West Lafayette

Symplectic Integrators Versus Ordinary-Differential-Equation Solvers for Hamiltonian Systems
Jon Lee, Wright Lab (FIB), Wright-Patterson Air Force Base

Scaling in Forced Laser Synchronization
Carlos L. Pando, Universidad Autonoma de Puebla, Mexico

Two-Dimensional Josephson-Junction Network Architecture for Maximum Microwave Radiation Emission
Joerg Oppenlaender and Werner Guettinger, University of Tuebingen, Germany

A Feedback Scheme for Controlling Dispersive Chaos in the Complex Ginzburg-Landau Equation
Georg Flatgen, Yannis G. Kevrekidis, Princeton University; Paul Kolodner, Bell Laboratories, Lucent Technologies

Chaos Synchronization and Riddled Basins in Two Coupled One-Dimensional Maps
Tomasz Kapitaniak, Technical University of Lodz, Poland; and Y. Maistrenko, Academy of Sciences of Ukraine, Ukraine

Lattice Boltzmann Equation Model for Potassium Dynamics in Brain
Longxiang Dai and Robert M. Miura, University of British Columbia, Canada

Non-Collision Singularities in a 6 Body Problem
Jeff Xia and *Todd Young*, Northwestern University

Stationary Solutions of an Integro-Differential Equation Modeling Phase Transitions: Existence and Local Stability
Adam Chmaj, Brigham Young University

Control of Impact Dynamics
Jan Awrejcewicz and Krzysztof Tomczak, Technical University of Lodz, Poland

Theoretical Analysis of Pattern Formation in Circular Domains
Gemunu H. Gunaratne, University of Houston

Transport Properties in Disordered Ratchet Potentials
Fabio Marchesoni, University of Illinois, Urbana

Numerical Simulation of Staanding Waves in a Vertically Oscillated Granular Layer
Chris Bizon, Mark Shattuck, Jack Swift, William McCormick, and Harry Swinney, University of Texas, Austin

Applications of the KAM Theory to Commensurate-Incommensurate Phase Transitions
Bambi Hu, Hong Kong Baptist University, Hong Kong and University of Houston

CONFERENCE PROGRAM

Wednesday, May 21

The Modeling of Self-Oscillating Regimes in Catalytic Reaction Dynamics
N. I. Koltsov, Chuvash State University, Russia

Image Encryption Based on Chaos
Jiri Fridrich, State University of New York, Binghamton

Integrals of Motion and the Shape of the Attractor for the Lorenz Model
Sebastien Neukirch and Hector Giacomini, Université de Tours,France

Dynamics of the Two-Frequency Torus Breakdown in the Driven Double Scroll Circuit
Murilo S. Baptista and *Ibere L. Caldas*, University of Sao Paulo, Brazil

Type-II Intermittency in the Driven Double Scroll Circuit
Murilo S. Baptista and *Ibere L. Caldas*, University of Sao Paulo, Brazil

Pulse Like Spatial Patterns Described by Higher Order Model Equations
A. I. Rotariu-Bruma and L.A. Peletier, University of Leiden, The Netherlands; and W. C. Troy, University of Pittsburgh

The Computer Analysis of Poincaré Cross-Sections in Chemical Reactions Dynamics
Kozhevnikov I.V. and Koltsov N.I., Chuvash State University, Russia

Modular Networks for Animal Gaits
Martin Golubitsky, University of Houston; Ian Stewart, University of Warwick, United Kingdom; *Pietro-Luciano Buono*, University of Houston; and J. J. Collins, Boston University

A Method for Solving the Linear Operator Problem <I>Ky=h(x)
L. K. Tolman, Brigham Young University

Convergence Theorems for the Method
Richard Wellman, Utah State University

On Some Random Generalized Functions Having a Mean
Manuel L. Esquivel, Universidade Nova de Lisboa, Portugal

Flow-Reversal Systems with Fast Switching
Jan Rehacek, Los Alamos National Laboratory; Alois Klic, and Pavel Pokorny, Institute of Chemical Technology, Czech Republic

Thursday, May 22

8:30 AM-9:30 AM

Chair: Rajarshi Roy, Georgia Institute of Technology
Ballroom I, II, III - Level B

IP10

Universal Spatio-Temporal Chaos in Large Assemblies of Simple Dynamical Units

Large assemblies of nonlinear dynamical units driven by a stochastic field with smooth spatial variation generate strong turbulence with various scaling properties. The driving field may actually be a self-generated internal field due to long-range mutual coupling. Besides being persistent over a finite parameter range, this type of turbulence is highly independent of what kind of dynamical units are involved, and whether or not each unit is coupled with its neighborhood. Underneath the amplitude field of our direct observation, a strongly intermittent field with a multifractal structure is discovered which is reminiscent of the energy dissipation field in the fully-developed hydrodynamic turbulence.

Yoshiki Kuramoto
Graduate School of Sciences and Department of Physics
Kyoto University

10:00 AM-12:00 PM

Ballroom I - Level B

MS44

Dynamical Systems Theory and Nonequilibrium Statistical Mechanics

The last few years have seen the growth of a new branch of statistical mechanics, the area of physics that deals with the properties of systems of large numbers of particles. This new branch - the applications of dynamical systems theory to the theory of transport in fluids and solids - is founded on fundamental mathematical ideas of Sinai, Ruelle, and Bowen, but has a history that reaches back to the 19th century development of statistical mechanics by Maxwell, Boltzmann, and Gibbs. Recent research has focused upon the relation between issues in transport theory such as the calculation of transport coefficients like viscosities, diffusion coefficients, etc., and the Lyapunov exponents and KS entropies that characterize the chaotic dynamics of the system. Since the last Snowbird meeting in 1995 where a similar minisymposium was organized and held, substantial advances have been made in calculating the dynamical quantities of interest and relating them to transport coefficients, and in understanding the relationship between the dynamical systems approach to transport and that of irreversible thermodynamics. Of particular interest in this connection is the role of entropy production in a fluid system, and how it can be related to various fractal structures in the phase space dynamics. The speakers are all recognized leaders in this field and have made very important contributions to it in the last few years.

Organizer: Robert Dorfman
University of Maryland, College Park

10:00 Lyapunov Exponents and Irreversible Entropy Production in Low Density Many-Particle Systems
Henk van Beijeren, University of Utrecht, The Netherlands; and Robert Dorfman, Organizer

10:30 Lyapunov Spectra of Various Model Systems in Nonequilibrium Steady States
Harald A. Posch and Christoph Dellago, University of Vienna, Austria

11:00 Entropy Production in Open Volume Preserving Systems
Pierre Gaspard, Universite Libre de Bruxelles, Belgium

11:30 Transport and Entropy Production in Low-Dimensional Chaos
Tamas Tel, W. Breymann, and J. Vollmer, Eotvos University, Hungary

10:00 AM-12:00 PM

Ballroom II - Level B

MS45

Dynamics of Laser Arrays: Coherence, Chaos and Control

Advances in the design and fabrication of laser arrays have led to great interest in the power, coherence, and stability properties of the light emitted by these arrays. This minisymposium will address important issues in the mathematical modelling of laser arrays including comparisons of predicted dynamics with experimental observations. The connections between coherence and dynamical behavior and the control of these properties will be an important aspect of the minisymposium presentations and discussions to be given by leading experts in the field. Advances in the design and fabrication of laser arrays have led to great interest in the power, coherence and stability properties of the light emitted by these arrays.

Organizer: Rajarshi Roy
Georgia Institute of Technology

CONFERENCE PROGRAM

Thursday, May 22

10:00 Nonlinear Dynamics of Semiconductor Laser Arrays
Herbert G. Winful, University of Michigan, Ann Arbor

10:30 Design of Laser Resonators for Enhanced Spatial Coherence and Mode Control
James R. Leger, University of Minnesota, Minneapolis

11:00 Two Coupled Lasers
Thomas Erneux, Université Libre de Bruxelles, Belgium; A. Hohl, A. Gavrielides, and V. Kovanis, Phillips Laboratory

11:30 Entrainment of Coupled Solid State Lasers
T. A. Brian Kennedy, Y. Braiman, A. Khibnik, and Kurt Wiesenfeld, Georgia Institute of Technology

10:00 AM-12:00 PM

Magpie A & B - Level B

MS46
Energy Transfer in Nonlinear Partial Differential Equations

In nonlinear and nonintegrable partial differential equations (PDEs) modeling physical systems, important phenomena are often understandable in terms of energy transfer among natural modes of the system. Such descriptions can be, for example, in terms of (nonlinear) bound state and radiation modes, or small scale and long scale structures. In this minisymposium some conservative and dissipative dynamical systems will be considered and analyzed from this perspective. Examples of phenomena to be examined are asymptotic stability, metastability, radiation damping, singularity formation in Hamiltonian systems, and turbulence in random and dissipatively perturbed Hamiltonian systems. The equations considered are nonlinear wave and Schrödinger equations and their perturbations. The methods used are quite broad and involve, for example, classical PDE and asymptotic methods, invariant manifolds, scattering theory and stochastic analysis. The purpose of this minisymposium is to present in a single forum recent evelopments on the question of energy transfer in nonlinear and nonintegrable PDEs.

Organizer: Michael I. Weinstein
University of Michigan , Ann Arbor

10:00 Self-Focusing of the Nonlinear Schrödinger Equation and Its Behavior Under Small Perturbation
George C. Papanicolaou, Stanford University

10:30 Invariant Manifolds for a Class of Dispersive, Hamiltonian, Partial Differential Equations
Claude-Alain Pillet, Universite de Geneve, Switzerland; and *Clarence Eugene Wayne*, Pennsylvania State University

11:00 On Oscillations of Solutions of Randomly Forced-Damped NLS Equations
Sergei B. Kuksin, Steklov Mathematical Institute, Russia

11:30 Resonances and Radiation Damping in Conservative Nonlinear Waves
Michael I. Weinstein, Organizer

10:00 AM-12:00 PM

Ballroom III - Level B

MS47
Control and Shadowing

The talks in this session discuss applications of control and shadowing. The applications include laboratory experiments with a bouncing ball and a double pendulum that use targeting to reach prespecified states; the control of pendulation in a crane attached to a rocking ship; theoretical and numerical results on control in a system whose phase space consists of chaotic sets and KAM surfaces; and a discussion of the limits of deterministic modeling. The notion of "control of chaos" has received a great deal of attention in recent years. The experiments to be discussed in this minisymposium are among the first to (1) deal directly with the "targeting of chaos" problem in a laboratory setting and (2) to discuss applications with real industrial/military importance.

Organizer: Eric J. Kostelich
Arizona State University

10:00 Controllable Targets for Use with Chaotic Controllers
Thomas L. Vincent, University of Arizona

10:30 A Chaotically Forced Pendulum: Ship Cranes at Sea
Guohui Yuan, Brian Hunt, Celso Grebogi, Edward Ott, and James A. Yorke, University of Maryland, College Park; and Eric J. Kostelich, Organizer

11:00 Targeting in Soft Chaotic Hamiltonian Systems
Christian G. Schroer and Edward Ott, University of Maryland, College Park

11:30 Limits to Deterministic Modeling
James A. Yorke, University of Maryland, College Park

10:00 AM-12:00 PM

Chair: Sharon R. Lubkin, University of Washington
Superior B - Level C

CP30
Biology

10:00 A Two-Dimensional Model of Human Walking
Susan J. Schenk, New Jersey Institute of Technology

10:20 Bifurcation Analysis of Nephron Pressure and Flow Regulation
Erik Mosekilde and Mikael Barfred, Technical University of Denmark, Denmark; and Niels-Henrik Holstein-Rathlou, University of Copenhagen, Denmark

10:40 Pattern Formation In Vitro
Sharon R. Lubkin, University of Washington

11:00 Population Dynamics of Dungeness Crab: Connecting Mechanistic Models to Data
Kevin Higgins and Alan Hastings, University of California, Davis; Jacob N. Sarvela, University of Texas, Austin; and Louis W. Botsford, University of California, Davis

11:20 Global Asymptotic Behavior and Dispersion in Size-Structured, Discrete Competitive Systems
John E. Franke, North Carolina State University; and Abdul-Aziz Yakubu, Howard University

11:40 Dynamics of Mass Attack, Spatial Invasion of Pine Beetles into Lodgepole Forests
Peter White and James Powell, Utah State University; Jesse Logan and Barbara Bentz, USFS Intermountain Research Station

10:00 AM-12:00 PM

Chair: Thomas W. Carr, Southern Methodist University
Superior A - Level C

CP31
Karhunen-Loeve Methods

10:00 A Study of Transition in Rayleigh-Benard Convection using a Karhunen-Loeve Basis
I. Hakan Tarman, King Fahd University of Petroleum and Minerals, Saudi Arabia

10:20 On Dynamical Systems Obtained Via Galerkin Projection onto Bases of KL-Eigenfunctions for Fluid Flows
Dietmar Rempfer, Cornell University

10:40 The Karhunen-Loeve Transformation: When Does it Work?
Michael Kirby, Colorado State University

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11:00 Coupled Mechanical-Structural Dynamical Systems: A Geometric Singular Perturbation-Proper Orthogonal Decomposition Approach
Ioannis T. Georgiou and Ira B. Schwartz, Naval Research Laboratory

11:20 Detecting Interacting Modes in Spatio-Temporal Signals
Christian Uhl, Max-Planck-Institute of Cognitive Neuroscience, Germany

10:00 AM-12:00 PM

Chair: Patrick D. Miller, Brown University
Wasatch A & B - Level C

CP32

Chaotic Advection, Turbulence, and Transport I

10:00 Chaotic Advection in an Array of Quasi-2D Vortices
S. R. Maassen, H. J. H. Clercx, and G. J. F. van Heijst, Eindhoven University of Technology, The Netherlands

10:20 Enhancement of Stirring by Chaotic Advection using Parameter Perturbation and Target Dynamics
Yechiel Crispin, Embry-Riddle University

10:40 Fractal Entrainment Sets of Tracers Advected by Chaotic Temporally Irregular Fluid Flows
Joeri Jacobs, Edward Ott, Thomas Antonsen, and James A. Yorke, University of Maryland, College Park

11:00 Geometrical Dependence of Finite Time Lyapunov Exponents and Transport
Xianzhu Tang, College of William and Mary and Columbia University; and Allen H. Boozer, Columbia University and Max-Planck Institute, Germany

11:20 Quantifying Transport in Numerical Simulations of Oceanic Flows
Patrick D. Miller and Christopher K. R. T. Jones, Brown University; Audrey M. Rogerson and Lawrence J. Pratt, Woods Hole Oceanographic Institution

11:40 Anomalous Dispersion in 2-d Turbulence
Antonello Provenzale, Instituto di Cosmogeofisica, Italy

10:00 AM-12:00 PM

Chair: Sue Ann Campbell, University of Waterloo, Canada
Maybird - Level C

CP33

Bifurcation and Symmetry

10:00 Stability of the Whirling Modes of a Hanging Chain (Kolodner's Modes)
Warren Weckesser, Rensselaer Polytechnic Institute

10:20 Instabilities of Spatio-Temporally Symmetric Periodic Orbits
A. M. Rucklidge, University of Cambridge, United Kingdom; and Mary Silber, Northwestern University

10:40 On a Neutral Functional Differential Equation Modelling a Simple Physical System
Sue Ann Campbell, University of Waterloo, Canada

11:00 Bifurcation Leading to Hysteresis
Gregory Berkolaiko, University of Strathclyde, United Kingdom

11:20 Feedback-Assisted Instability Detection
Jason S. Anderson, Georg Flatgen, and *Yannis G. Kevrekidis*, Princeton University; Katharina Krischer, Fritz-Haber-Institüt der Max-Planck-Gesellschaft, Germany; and Ramiro Rico-Martinez, Instituto Tecnologico de Celaya, Mexico

11:40 Grazing Bifurcations in a Piezoelectric Impact Oscillator
Sandeep T. Vohra, Naval Research Laboratory

12:00 An Introduction to Groebner Bases and Invariant Theory
T. K. Callahan and Edgar Knobloch, University of California, Berkeley

1:30 PM-2:30 PM

Chair: Vered Rom-Kedar, Weizmann Institute of Science, Israel
Ballroom I, II, III - Level B

IP11

Complex Ginzburg-Landau Equations as Perturbations of Nonlinear Schrödinger Equations

General complex Ginzburg-Landau (CGL) equations are considered as perturbations of general nonlinear Schrödinger (NLS) equations over a one dimensional periodic domain. We identify some structures in the phase space of the NLS equations that persist under the CGL perturbation, where "persists" means to be approximated in the C infty topology by a CGL structure as the perturbation tends to zero. Such structures necessarily play an important role in the dynamics of the CGL global attractor. We find criteria for NLS rotating waves and traveling waves to persist and, in some cases, determine their dynamical stability. In the Lyapunov case this characterizes all omega-limit sets of the flow and a complete bifurcation analysis can be carried out. When the focusing NLS equation is perturbed, we show that none of the NLS orbits homoclinic to rotating waves persist, but rather distinct homoclinic structures are produced by the CGL perturbation.

C. David Levermore
Department of Mathematics
University of Arizona

3:00 PM-5:00 PM

Ballroom I - Level B

MS48

Noise and Heteroclinic Phenomena

Homoclinic and heteroclinic cycles are common in nonlinear dynamics, usually arising in global bifurcations but also occurring, in a structurally stable way, in some systems with symmetry. Introduction of noise to systems that exhibit homoclinic/heteroclinic phenomena can result in qualitative changes in the dynamics, with the appearance of new characteristic timescales and the masking of chaotic behaviour being common. Because deterministic equations usually

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are not precise descriptions of physical systems, it is important in applications to know which features of the deterministic dynamics persist under the addition of noise. This minisymposium looks at the effect of noise on a number of systems that have homoclinic, heteroclinic, or related phenomena. Various approaches will be discussed, including methods based on stochastic differential equations, Fokker-Planck equations, and numerical integration/simulation.

Organizers: Vivien Kirk, University of Auckland, New Zealand; and Emily Stone, Utah State University

10:00 Probability Densities for Qualitatively Modified Dynamics
Rachel Kuske, Tufts University; George Papanicolaou, Stanford University; and Steve Baer, Arizona State University

10:30 Noise-Controlled Dynamics in Normal Forms
Grant Lythe, Los Alamos National Laboratory; and Steve Tobias, University of Colorado, Boulder

11:00 Noisy Cycles, the Sequel
Emily F. Stone, Organizer; and Dieter Armbruster, Arizona State University

11:30 A Heteroclinic Network with Noise
Vivien Kirk, Organizer; and Mary Silber, Northwestern University

3:00 PM-5:00 PM

Ballroom II - Level B

MS49

Melnikov Methods for Partial Differential Equations

In the past two years, several important breakthroughs have been made in applying the Method of Melnikov to demonstrating the existence of transverse homoclinic orbits and chaotic dynamics in near-integrable partial differential equations. This minisymposium will present some of them. The presented work deals with conservative and dissipative perturbations of the nonlinear Schrödinger equation, and the Maxwell-Bloch equations that describe the dynamics of light in laser cavities. The techniques used in investigating these problems are the inverse spectral theory for integrable partial differential equations with periodic boundary conditions, Backlund transformations and the dressing method, invariant manifold theory in infinite-dimensional settings, k normal forms, geometric singular perturbation theory and the theory of orbits homoclinic to resonance bands, the energy-phase method for detecting multi-pulse homoclinic orbits, and numerical nonlinear spectral analysis. Careful comparisons with numerical simulations will also be presented.

Organizers: Constance M. Schober, Old Dominion University; and Gregor Kovacic, Rensselaer Polytechnic Institute

3:00 The Nonlinear Schrödinger Equation: Asymmetric Perturbations, Traveling Waves and Chaotic Structures
Constance M. Schober, Organizer

3:30 Homoclinic Orbits in the Maxwell-Bloch Equations of Nonlinear Laser Optics
Gregor Kovacic, Organizer; Jiyue J. Li and *Victor Roytburd*, Rensselaer Polytechnic Institute; and Thomas A. Wettergren, Naval Undersea Warfare Center

4:00 The Fate of Traveling Waves of the Nonlinear Schrödinger Equation under Ginzburg-Landau Type Perturbations
C. David Levermore, Gustavo Cruz-Pacheco, and *Benjamin P. Luce*, Los Alamos National Laboratory

4:30 Smale Horseshoes in Perturbed Nonlinear Schrödinger Equations
Charles Y. Li, Massachusetts Institute of Technology

3:00 PM-5:00 PM

Magpie A & B - Level B

MS50

Nonlinear Dynamics and Pattern Formation in Combustion

We consider both gaseous and solid fuel combustion, e.g., employed in combustion synthesis of materials. Since the structure of the material produced, the propagation velocity, and maximum temperature are determined by the mode of propagation of the combustion wave, assessment of the quality of the material produced and the rate of flame spread must be considered because the maximum temperatures and velocities attained in dynamical modes can well exceed estimates based on steady state analysis. Analytical, numerical, and experimental approaches are employed in a variety of problems, including the dynamics of cellular, target, spinning, and spiral flames.

Organizer: Vladimir A. Volpert
Northwestern University

3:00 Standing Waves, Heteroclinic Connections, and Parity Breaking in Bifurcations from Ordered States of Cellular Flames
Michael Gorman, University of Houston; and Kay Robbins, University of Texas, San Antonio

3:30 Excitability in Premixed Gas Combustion
Howard Pearlman, NASA Lewis Research Center

4:00 Spatio-Temporal Pattern Formation in Combustion
Alvin Bayliss and *Bernard J. Matkowsky*, Northwestern University

4:30 Nonlinear Dynamics in Combustion Synthesis of Materials
Vladimir A. Volpert, Organizer

3:00 PM-5:00 PM

Ballroom III - Level B

MS51

Riddling in Chaotic Systems

Riddling and related bifurcations in dynamical systems with symmetric invariant subspaces have been an area of recent study. Riddling refers to the situation where the basin of a chaotic attractor is riddled with holes that belong to the basin of another attractor. Current directions of research consist of theoretical, numerical, and experimental exploration of various physical consequences associated with riddling and related bifurcations. One such consequence is on-off intermittency. The presentations in this minisymposium deal with several forefront problems on riddling. Topics to be covered include riddling bifurcation, blowout bifurcation, intermingled basins, and on-off intermittency in coupled map lattices, and unstable periodic-orbit theory of blowout bifurcation.

Organizer: Ying-Cheng Lai
University of Kansas

3:00 Riddling Bifurcation in Chaotic Dynamical Systems
Celso Grebogi, University of Maryland, College Park

3:30 Blowout-Type Bifurcations in Symmetric Systems
Peter Ashwin, University of Surrey, United Kingdom

4:00 Synchronized Chaos, Intermingled Basins and On-Off Intermittency in Coupled Dynamical Systems
Mingzhou Ding, Florida Atlantic University

4:30 Characterization of Blowout Bifurcation by Unstable Periodic Orbits
Ying-Cheng Lai, Organizer

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Chair: Michael E. Davies, University College London, United Kingdom
Maybird - Level C

CP34
Time Series and Signal Processing

3:00 No Noise is Good Noise?
Mark Muldoon, J. P. Huke, and D. S. Broomhead, University of Manchester Institute of Science and Technology, United Kingdom

3:20 Testing Nonlinear Markovian Hypotheses in Dynamical Systems
Christian Schittenkopf, Technische Universitat Munchen, Germany and Siemens AG, Germany; and Gustavo Deco, Siemens AG, Germany

3:40 Is There a Deterministic Relation (Phase Locking) Between Sunspot Cycles and Interdecadal Variability of Atmospheric Temperature?
Milan Palus, Institute of Computer Science, AS CR, Czech Republic; Dagmar Novotna, Institute of Atmospheric Physics, AS CR, Czech Republic; and Ivana Charvatova, Institute of Geophysics, AS CR, Czech Republic

4:00 Detecting Singularities of Non-Deterministic Dynamics
Joseph P. Zbilut, Rush Medical College; David D. Dixon, University of California, Riverside; and Charles L. Webber, Jr., Loyola University Chicago

4:20 Takens Embedding Theorems for Forced and Stochastic Systems
Jaroslav Stark, University College London, United Kingdom

4:40 Time-Series Analysis Tools for Nonlinear System Identification
Joseph Iwanski and Elizabeth Bradley, University of Colorado, Boulder

5:00 Chaos and Detection
Andrew M. Fraser, Portland State University

3:00 PM-5:00 PM

Chair: Diego del Castillo-Negrete, University of California, San Diego
Wasatch A & B - Level C

CP35
Chaotic Advection, Turbulence, and Transport II

3:00 Acoustic Turbulence
Alexander M. Balk, University of Utah

3:20 Interfacial Turbulence at Large Prandtl Number
P. Colinet and J. C. Legros, Universite Libre de Bruxelles, Belgium

3:40 Anomalous Transport in an Incompressible, Temporally Irregular Flow
Shankar C. Venkataramani, James Franck Institute; Thomas M. Antonsen Jr. and Edward Ott, University of Maryland, College Park

4:00 Space-Time Modeling and Pattern Formation in Rotating Flows
Erik A. Christensen, Levich Institute, City College of CUNY and New Jersey Institute of Technology; Nadine Aubry, New Jersey Institute of Technology, and Levich Institute, City College of CUNY; Jens N. Sorensen and Martin O. L. Hansen, Technical University of Denmark, Denmark

4:20 Nonlinear Dynamics of Electrochemical Oscillations, Surface, Morphology, and Corrosion
Elia V. Eschenazi and Ninj Balla, Xavier University of Louisiana

4:40 Chaotic Transport in a Chain of Vortices: Anomalous Diffusion and Levy Statistics
Diego del Castillo-Negrete, University of California, San Diego

3:00 PM-5:00 PM

Chair: Jinqiao Duan, Clemson University
Superior B - Level C

CP36
Partial Differential Equations

3:00 Analytical Properties of PDE Jet Engine Models
Hoskuldur Ari Hauksson, University of California, Santa Barbara; Andrzej Banaszuk, University of California, Davis; Bjorn Birnir and Igor Mezic, University of California, Santa Barbara

3:20 Analytic Aspects and Special Solutions of Nonlinear Partial Differential Equations
S. Roy Choudhury, University of Central Florida

3:40 Persistence of Invariant Manifolds for Nonlinear PDEs
Don A. Jones, Arizona State University; and *Steve Shkoller*, University of California, San Diego

4:00 Dynamics of a Nonlocal Kuramoto-Sivashinsky Equation
Jinqiao Duan and Vincent J. Ervin, Clemson University

4:20 Space Analyticity on the Attractor Generated by the Set of All Stationary Solutions for the Kuramoto-Sivashinsky Model
Zoran Grujic, Indiana University, Bloomington

4:40 Higher-Order Bistable Systems in One Space Dimension
William D. Kalies, J. Kwapisz, R. C. A. M. VanderVorst, and T. Wanner, Georgia Institute of Technology

3:00 PM-5:00 PM

Chair: Hans True, Technical University of Denmark, Denmark
Superior A - Level C

CP37
Engineering and Control

3:00 Stabilization of Uncertain Mechanical Systems Using Dynamic Feedback
Ernest Barany and Richard Colbaugh, New Mexico State University, Las Cruces

3:20 On Time Optimal Control Trajectories of Biotechnological Processes
Djamal Atroune, University of Georgia

3:40 Nonlinear Regenerative Machine Tool Vibrations
Gabor Stepan, Technical University of Budapest, Hungary

4:00 Application of Symbolic Dynamics to Modeling and Control of an Internal Combustion Engine
C. Stuart Daw and Matthew B. Kennel, Oak Ridge National Laboratory; and *Charles E. A. Finney*, University of Tennessee, Knoxville

4:20 Stabilization of Uncertain Mechanical Systems Using Bounded Controls
Richard Colbaugh, Ernest Barany, and Kristin Glass, New Mexico State University, Las Cruces

4:40 Dynamical Response of a Spherical Pendulum to Roll and Pitch Excitation
Michael D. Todd and Sandeep T. Vohra, Naval Research Laboratory; and Frank A. Leban, Naval Surface Warfare Center

5:00 On a New Route to Chaos in Railway Dynamic
Hans True, Technical University of Denmark, Denmark

5:20 PM

Conference Adjourns

Fax & E-mail capabilities

SIAM cannot offer e-mail access for individual attendees. We suggest you bring your own laptop computer and use hotel facilities. If you do not have your own personal laptop computer, the hotel business office offers this service at a nominal fee.

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ABSTRACTS

Fourth SIAM Conference on

APPLICATIONS of DYNAMICAL SYSTEMS

May 18-22, 1997

Snowbird Ski and Summer Resort • Snowbird, Utah

CP01
Phase Jumps of π in a Laser with a Periodically Forced Injected Signal

Amplitude and phase dynamics of a laser with injected signal are analyzed as the injection amplitude is varied by a small periodic term. Two-timing analysis yields slow time evolution equations of a periodically forced Toda oscillator. The dynamics near resonance are shown to be of particular interest. Control of the output amplitude and jumps of π in the phase by changing the injection amplitude and frequency are discussed.

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CP01
Synchronized Patterns in Coupled Lasers

The Maxwell-Bloch equations for a laser with saturable absorber may undergo a Hopf bifurcation which, since there is no distinguished polarization direction, occurs in an equivariant setting as a Hopf bifurcation with $O(2)$-symmetry. If several such lasers are coupled in a ring, the full system possesses a $D_n \times O(2)$-symmetry. The Hopf bifurcation with this symmetry predicts a number of different states which can be classified group-theoretically. These states and their symmetry properties are described and intrepreted as distinct synchronized radiation patterns for the coupled laser system. Moreover, the dynamics of the underlying normal form shows structurally stable heteroclinic cycles which induce transitions between different patterns.

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CP01
Spatio-Temporal Dynamics of Broad-Area Semiconductor Lasers with Optical Feedback

The spatio-temporal behavior of broad-area semiconductor lasers with conventional optical feedback and grating feedback is studied experimentally. We investigate the effects of the collimating lens position, the external cavity length, the optical feedback level, and the injection current. In addition to interesting nonlinear dynamics, such practical effects as lateral-mode selectivity and beam quality enhancement are exploited to build high power external-cavity diode laser sources with high temporal and good spatial coherence.

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CP01
Bifurcation Diagram of Two Lasers with Injected Field

We study the dynamics of two coupled solid state lasers subject to an injected field. Using singular perturbation and averaging techniques we arrive at a phase model for which we present a comprehensive bifurcation analysis. We particularly study routes to full entrainment as the injected field amplitude increases and observe that the entrainment does not monotonically improve with the injected field strength. Our numerical simulations suggest that the phase model captures the relevant dynamics well beyond the asymptotic regime in which it is derived.

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CP01
Nonlinear Dynamics of Semiconductor Laser Arrays

The nonlinear dynamics of multi–stripe semiconductor lasers is investigated numerically as a function of the injection current, and number and width of and separation between stripes, and shown to exhibit a rich behaviour characterized by regular or coherent phenomena, filamentation, incoherence, nonlinear interactions between the stripes, and chaos. For two–stripe lasers, it has been found that the average intensity may exhibit spatio–temporal oscillations, whereas, for five–stripe ones, bursting phenomena in the three central stripes was found.

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CP01
Homoclinic Orbits for the Second Harmonic Generation of Light in an Optical Cavity

We present two large families of Šilnikov-type homoclinic orbits that exist in a model of an asymmetric crystal interacting with light in a passive optical cavity. This crystal generates the second harmonic frequency. The resulting brightness of the light with the fundamental and second harmonic frequencies is described by a two degree of freedom near integrable system which is close to a 2:1 resonance. These families of homoclinic orbits give rise to chaotic dynamics in the model. In order to obtain these orbits we use a combination of the Melnikov method and geometric singular perturbation theory.

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CP02

Fast Resonance Shifting as a Mechanism of Instability in Dynamics Illustrated by Comets

Fast resonance shifting is a newly confirmed mechanism for instability of motion in conservative systems. It was originally observed numerically in 1989 as a way a particle can rapidly hop between resonant periodic orbits in the three-body problem, traversing large regions of the phase space. The motion of the zero mass particle was about the Earth under the gravitational perturbation of the Moon. Unlike the standard process of Arnold diffusion which predicts that this process should take on the order of a billion years, this resonance shifting, termed the hop, took about 30 days. Because of the rapidity of the hop, it was felt that perhaps there were numerical errors. However, in 1995, it was discovered by Brian Marsden of the Harvard-Smithsonian Center for Astrophysics, that perhaps some comets moving about the Sun were performing the hop. This was confirmed, and a paper explaining this and its connection with the work of John Mather, will appear in The Astronomical Journal. It turns out that the hop occurs at a region about the secondary mass called the 'fuzzy boundary' where it is conjectured a hyperbolic tangle exists. The fuzzy boundary of the Moon also has important applications to the motion of spacecraft, and using it, the author found a new low route to the Moon in 1990 which was demonstrated by a Japanese spacecraft in 1991 arriving at the Moon in October of that year.

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CP02

Hamiltonian G-space Normal Forms as a Geometric Framework for Perturbation Theory

Hamiltonian G-space normal forms are appropriate as a geometric framework for perturbation theory when a system's integrability comes from a non-Abelian symmetry group. A particular normal form appearing in Dazord and Delzant (1987), which we call *action-group coordinates*, is a 'non-Abelian' generalization of action-angle coordinates. We use these coordinates to generalize a theorem of Nekhoroshev (1977), deducing exponential estimates for momentum maps in a class of Hamiltonian G-spaces with 'almost G-invariant' Hamiltonian.

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CP02

Necessary and Sufficient Conditions for Finite-Time Blow-Up in ODE's

The problem of finding conditions on a nonlinear vector field so that the solutions have finite time singularities is discussed. A general theorem which provides necessary and sufficient conditions for the blow-up, in real finite time, of the general solution to an autonomous, n-dimensional nonlinear ODE is presented. This theorem involves only the asymptotic form of the local series solution in complex time and thus provides a simple algorithm for determining the existence of finite time blow-up. The application of this new result to fluid mechanics and Hamiltonian dynamics is also considered.

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CP02

On Lie Transforms for Differential Systems

We deal with Lie transforms for ordinary differential systems with a small perturbation. The theory, presented firstly by Deprit for Hamiltonian systems and extended thereafter by Kamel and Henrard for differential equations, has been recently generalized by Meyer for one contravariant tensor fields. Here we give a systematic deduction of all the algorithms, presenting also some variations for specific cases as well as some combinations of the different approaches useful when the perturbation is composed by terms of different type.

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CP02

Evolution Towards Symmetry

We trace the long-time effect of the asymmetries in a Hamiltonian which becomes slowly symmetric in time. We establish the relation between evolution towards symmetry and dissipative mechanics while using the techniques of averaging and adiabatic invariants, supported by Mathematica 2.2. For 2-dof we apply the Arnold-Neihstadt theory of passage through resonance. The analysis reveals significant asymmetric dynamics even when the asymmetric contributions to the potential have become negligibly small (joint work with R.A.J.G.Huveneers).

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CP03
Dynamical Friction Modeling

We derive a two-degree-of-freedom dynamical model of friction from a macroscopic description of the interactions between nominally flat surfaces. In particular, coupling is introduced between the horizontal motion and the separation of the surfaces. The nonlinear model is studied and found to qualitatively agree with experimentally observed properties of dynamical friction. For example, stick-slip behavior is found to be associated with a Hopf bifurcation from the steady-state equilibrium.

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CP03
Graph Theoretic Implications for Piecewise Linear Systems of Arbitrary Dimension

Ideas from graph theory are used to produce a basis for all possible periodic orbits to the piecewise linear system of a rocking block confined between two vertical walls. This approach uncovers previously unknown solutions to the problem which are subsequently observed in numerical simulations. The method is then applied to a one dimensional array of m impact oscillators used to model the dynamics of a heat exchanger. It is shown that the total number of distinct impacting configurations is given by the $(m+4)th$ Fibonacci number. It is suggested that this method can be adapted to other piecewise linear systems of arbitrary dimension.

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CP03
Homoclinic Orbits and Localized Buckling of Cylindrical Shells

Experimentally the buckling of a long elastic cylindrical shell under axial compression occurs locally along the axial length. However the standard analytic approach assumes the buckle pattern comprises of an interaction of periodic eigenmodes axially and circumferentially. We introduce the von Karman–Donnell equations, their discretization, and seek homoclinic orbits for the resulting system of o.d.es. These yield axially localized solutions as observed experimentally. Excellent agreement with experiments is achieved with fewer modes than other methods.

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CP03
Forced Oscillations of a Discretely Supported Nonlinear String Using Nonsmooth Transformations

We analyze forced oscillations of a string on a nonlinear discrete foundation. Applying nonsmooth transformations of the spatial variable (Pilipchuck, 1985), we eliminate singularities from the equations of motion and obtain two nonlinear nonhomegeneous boundary value problems (BVPs); these are solved with a perturbation method. The associated boundary conditions are +smoothening relations+ related to the transformations. As an application, localized oscillations of the string are studied, and discreteness effects are included in the analytical results.

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CP03
Stochastic Effect on Chaotic Dynamics of Cutting Process

A model of the cutting process is formulated based on a random variation of the specific cutting resistance. The cutting resistance is generated as a simple one-dimensional univariate Gaussian process using the spectral representation method. The random responses are discussed and compared with the deterministic ones within the ranges of parameters where chaotic motion occurs. Contrary to a claim for continuous systems, in which the variance of the noise dampens the chaotic vibration, such a behavior is not observed in the discontinuous system. The chaotic response is still present and the stochasticity induces only huge impact forces during the transient period.

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CP04
Nonlinear Polarization-Mode Dispersion in Optical Fibers with Randomly Varying Birefringence

Randomly varying birefringence leads to nonlinear polarization-mode dispersion (PMD) in addition to the well-known linear PMD. Here we calculate the variance of the field fluctuations produced by this nonlinear PMD. We also derive the equilibrium probability distributions for these PMD terms, and track the evolution of the polarization state's probability distribution from its initial condition to its steady-state uniform distribution on the Poincaré sphere.

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CP04
Pulse Dynamics in Fiber Lasers

A comprehensive theoretical treatment of the modelocking pulse dynamics in a fiber laser cavity with a saturable Bragg reflector is given. The governing pulse dynamics is shown to be given by a modified Ginzburg-Landau equation with time dependent gain and diffusion terms. In a particular asymptotic limit, chirped solitary wave solutions are shown to exist and we consider their stability. Analytic and numerical simulations show the derived model to be in quantitative agreement with experimental results.

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CP04
Phase Dynamics in Optical Communications

Inverse scattering theory and associated soliton perturbation theories have been essential for the description of soliton communications systems modeled by (f)NLS and its near-integrable counterparts. In recent work, semiclassical modulation theory using low genus solutions of the (d)NLS was successfully applied to describe NRZ pulse propagation. In this talk, we take the point of view that the theory of N-phase solutions of integrable evolution equations unifies soliton and NRZ work. After showing how the μ-variable approach can be used to obtain several well known results from optical soliton theory, an analysis of phase shifts and phase dynamics is carried out. The concept of the geometric phase for solitons is also reviewed, and finite-time phase shift formulae are generated. Phase dynamics are often critical in optical communications devices, and this approach provides a natural way to analyze them.

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CP04
Switching-Induced Timing Jitter in Nonlinear Optical Loop Mirrors

The interaction of two copropagating pulses of different frequencies in a nonlinear optical loop mirror switch is investigated. An analytic solution in the limit of large velocity difference is found. This analysis, as well as numerical studies, demonstrates signal pulse acceleration due to control pulse evolution.

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CP04
Timing Jitter Reduction in a Fiber Laser Mode-Locked by an Input Bit Stream

All-optical timing recovery devices offer an efficient way of reducing timing jitter in long-distance communication systems. We perform analytical and numerical studies of timing jitter reduction in a clock-recovery device in which a data stream is used to mode-lock a fiber laser through the effect of cross-phase modulation. This situation is analyzed in the soliton limit where the laser pulses are close to optical solitons and the effect of the data steam on the laser pulses is predicted using soliton perturbation theory. Analytical and numerical results obtained here show a significant reduction in the rms timing jitter in the output laser pulse stream from the level present in the input data stream.

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CP04
Optical Pulse Dynamics in Dispersion Managed Fibers

For both soliton and non-return-to-zero (NRZ) data formats transmission in optical fibers can be significantly improved by periodically varying the group-velocity dispersion. Here, in the short period limit an averaged pulse evolution equation is derived, resulting in a nonlinear Schrödinger (NLS) equation with phase-independent perturbations that is relatively easy to deal with. In the soliton case, analysis indicates that soliton-like pulses are possible, and a theoretical expression for pulse energy in terms of the dispersion map parameters is obtained.

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CP05
Hopf's Last Hope: Spatiotemporal Chaos in Terms of Unstable Recurrent Patterns

Spatiotemporally chaotic dynamics of a Kuramoto-Sivashinsky system is described by means of an infinite hierarchy of its unstable spatiotemporally periodic solutions.

An intrinsic parametrization of the corresponding invariant set serves as accurate guide to the high-dimensional dynamics, and the periodic orbit theory yields several global averages characterizing the chaotic dynamics.

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CP05

Symplectic Integrators Versus Ordinary-Differential-Equation Solvers for Hamiltonian Systems

In this talk, we compare the performance of symplectic integrators and ordinary-differential-equation (ODE) solvers for some Hamiltonian systems. Considered here are the symplectic integrators of second-order (Feng, Ruth, Friedman & Auerbach), fourth-order (Forest & Ruth, Candy & Rozmus) and sixth-order (Yoshida), and the ODE solvers of DEABM and DERKF (Shampine) of the SLATEK library and LSODE (Hindmarsh) of ODEPACK. These integrators and solvers are used for trajectory computation of the Holmes oscillator, two-body central force field motion, Henon-Heiles system, and Fermi-Pasta-Ulam chain. The main observation is that up to 10^8 iterations ODE solvers perform just as well as symplectic integrators in accuracy, but fall short in efficiency.

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CP05

Characterization of Blowout Bifurcation by Unstable Periodic Orbits

Blowout bifurcation in chaotic dynamical systems occurs when a chaotic attractor, lying in some invariant subspace, becomes transversely unstable. We establish quantitative characterization of the blowout bifurcation by unstable periodic orbits embedded in the chaotic attractor. We argue that the bifurcation is mediated by changes in the transverse stability of an infinite number of unstable periodic orbits. There are two distinct groups of periodic orbits: one transversely stable and another transversely unstable. The bifurcation occurs when some properly weighted transverse eigenvalues of these two groups are balanced.

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CP05

From Billiards to Brains - Applying Periodic Orbit Theory to Mammalian Neuronal Networks

Characterizing mammalian neuronal networks through unstable periodic orbits has much attraction. Despite recent attempts to apply parametric control to such systems through unstable orbit information, rigorous proof for the existence of such orbits was lacking. Experimental data from both rat neuronal networks and human epileptic foci will here be presented, and analyzed both with recurrence methods and a recent transformational technique. The implications of these findings will be discussed.

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CP05

Detecting Unstable Periodic Orbit in Experimental Data

A general nonlinear method to extract unstable periodic orbits from chaotic time series is proposed. Utilizing the estimated local dynamics along a trajectory, we devise a transformation of the time series data such that the transformed data is concentrated on the periodic orbits. Thus, one can extract unstable periodic orbits from the transformed data by looking for peaks in a histogram approximation of its distribution function. In the presence of noise, the statistical significance of the results is assessed using surrogate data.

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CP06

Dynamic Period-Doubling Bifurcations of a Unimodal Map

We consider period-doubling bifurcations of a general one-dimensional unimodal map as a control parameter is swept slowly through the autonomous bifurcation point. Matched asymptotic expansions are used to find invariant manifolds for the period-1 and period-2 regions. A uniformly valid triple-deck MAE describes the transition of typical trajectories from the neighbourhood of the repelling period-1 manifold to the period-2 manifold. The expansion shows explicitly the effect on the transition of both sweep-rate and noise.

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CP06

Finding All Periodic Orbits of Maps Using Newton Methods: Sizes of Basins

For a diffeomorphism F on $\mathbb{R}^2$, it is possible to find period k orbits of F by applying Newton methods to the function $F^k - I$, (I the identity function). For an initial point x, if the process converges to a point p which is a period k point of F, we say x is in the Newton basin of p. We investigate the size of the Newton basin and how it depends on p and k.

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CP06

Nonanalytic Perturbation of Complex Analytic Maps

This study provides some connections between complex analytic maps of the complex plane and more general real analytic maps (or C^∞ maps?) of $\mathbf{R}^2$. We perform a numerical case study on the families of maps of the plane given by

$$z \to f_A(z, C) \equiv z + z^2 + C + A\overline{z}$$

where z is a complex dynamic (phase) variable, and C and A are complex parameters. Note that for $A = 0$, the resulting two-parameter family is a complex quadratic family. For $A \neq 0$, the map fails to be complex analytic, but is still analytic (quadratic) when viewed as a map from $\mathcal{R}^2$ to itself. We treat A in this family as a perturbing parameter and ask how the two-parameter bifurcation diagrams in the C parameter plane change as the perturbing parameter A is varied. The most striking phenomenon that appears as A is varied is that bifurcation points in the C plane for the $A = 0$ case evolve into fascinating bifurcation regions in the C plane for nonzero A. The points we concentrate on for $A = 0$ are contact points between "bulbs" of the corresponding Mandlebrot set.

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CP06

Dynamics of Non-Expanding Maps & Applications in Discrete Event Theory

Deterministic or stochastic maps which are non-expansive in the sup norm arise naturally in a number of applications, including discrete event systems, queuing theory, and dynamic programming. I will discuss deterministic non-expansive maps (mostly those that are also monotonic) from a dynamical point of view. At one level the dynamics of these maps is trivial; the most interesting behaviour is periodic. Nontheless there are natural dynamical questions that are important for the applications, and interesting mathematically. These include, but are not limited to, the existence of fixed points, the possible periods that may occur, and questions about asymptotic behaviour.

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CP06

The Dynamics of Some Digital Filters

A class of digital filters are described by the map $f(x,y) = (y, (-x + ay) mod.1)$ on the unit square, where a is an integer with —a—¡2. These maps, whose dynamics was first considered in the engineering literature, relate to a classical result by Minkowski. Their dynamical properties are not understood for most non integer values of a. Using renormalization techniques, we describe the dynamics of a few examples. (Joint work with Roy Adler and Bruce Kitchens)

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CP06

Collapsing of Chaos

We discuss the computational collapsing effect of a family of chaotic maps: $f_l(x) = 1 - |2x - 1|^l, l > 2$. i.e., a large number of initial conditions are eventually mapped to an unstable fixed point. We rigorously prove that this effect is independent of the precision of a computer, and it does not vanish as we increase the precision. In fact, this effect is closely related to correlation dimension of the attractor.

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CP07

The Application of the Direct Scattering Transform to the NRZ-to-Soliton Data Conversion Problem

We apply the direct scattering transform to analyze the conversion of phase modulated non-return-to-zero signal to the soliton format in the line with the sliding frequency guiding filters. Based on this we propose a recipe to optimize this conversion.

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CP07

Mass Exchanges Among Korteweg-de Vries Solitons

We consider multisoliton solutions of an integrable vector version of the Korteweg-de Vries (KdV) equation having the property that the sum of the vector components satisfies the scalar KdV equation. The results are interpreted as a way of assigning internal degrees of freedom to the solitons of the KdV equation. Each of the field components carries its own conserved mass, and in the process of collision solitons exchange mass of different types. The amount of mass shared during soliton collisions is calculated explicitly, revealing that in each pairwise collision the smaller (and slower) of the two solitons always gives up more mass than it had initially. This leads to a mass deficit, as the smaller soliton borrows against the continuum.

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CP07

Soliton Stability in Optical Transmission Lines using Semiconductor Amplifiers and Fast Saturable Absorbers

Soliton stability has been examined in a cascaded transmission system based upon standard monomode fibers with in-line seminconductor optical amplifiers (SOAs), sliding filters and saturable absorbers (SAs). Stabilization of pulse propagation in such a system can be achieved with a proper choice of the filter and SA parameters. Conditions of the stable propagation, including a critical sliding rate are determined. The impact of the saturable absorber on the soliton stability will also be discussed.

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CP07

Noisy Quasi-Periodicity in the Simulation of the Discrete Nonlinear Schrödinger Equation

We study numerically the homoclinic structures in the nonlinear
Schrödinger (NLS) equation, which possesses exact solutions found by Ablowitz & Herbst (1990). By using the integrable difference scheme (Ablowitz & Ladik 1976) for the NLS equation, the Runge-Kutta method for time integration and changing numerical precisions, we find that periodic and quasi-periodic motions are generated instead of homoclinic orbits. The periods are proportional to $-\ln \epsilon/\Omega_i$, where ϵ is the magnitude of numerical errors and Ω_i is the linear growth rate of the unstable modes. For the periodic case, this property coincides with the estimate of the mean passage time in the structually stable heteroclinic cycles in the dynamical systems with symmetry and random perturbations shown by Stone and Holmes (1990), if constant terms are neglected in their expression. An application of the homoclinic solutions to the motion of a closed vortex filament is also discussed.

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CP07

Vector Solitons and Their Internal Oscillations in Birefringent Nonlinear Optical Fibers

In this paper, single-hump vector solitons and their internal oscillations in birefringent nonlinear optical fibers are studied. It is found that the total number of single-hump vector solitons is continuously infinite and their polarizations can be arbitrary. The internal oscillations of these vector solitons are investigated by the linearization method. All the eigenmodes of the linearized equations around the vector solitons are determined. The discrete eigenmodes cause to the vector solitons permanent internal oscillations which visually appear to be a combination of translational and width oscillations in the A and B pulses. Lastly, the asymptotic states of the perturbed vector solitons are studied within both the linear and nonlinear theory. It is found that the state of internal oscillations of a vector soliton is always unstable. It invariably emits energy radiation and eventually evolves into a single-hump vector soliton state.

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CP08

A Leading-Order Singular Hamiltonian Perturbation Method in Fluid Dynamics

We consider the question of constructing a singular Hamiltonian perturbation method for fluids with generalized Poisson brackets. In partial answer to this question we have found a leading-order singular Hamiltonian perturbation method by combining asymptotic perturbation expansions with preservation of the Hamiltonian formulation. These leading-order results have been exemplified by a systematic derivation of the Hamiltonian formulation for the incompressible, homogeneous fluid equations via a Machnumber expansion and for the barotropic quasi-geostrophic fluid equations via a Rossby-number expansion.

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CP08

Variational Principle for Bifurcations in One Dimensional Hamiltonian Systems

We consider the one dimensional bifurcation problem $u'' + \lambda u = N(u)$ with two point boundary conditions and where $N(u)$ is a general nonlinear term which may also depend

on the eigenvalue λ. We show that there exists a variational principle for the lowest eigenvalue of the linear problem which can be extended to the nonlinear problem to obtain the complete bifurcating branch. We find that $\lambda = \max[(\int_0^{u_m} N(u)du + (1/2)K(u_m))/\int_0^{u_m} ug(u)du]$, where u_m denotes the amplitude and the maximum is taken over all positive functions g such that $g(0) = 0$, $g' > 0$. The function $K(u_m)$ is obtained from the solution of the linear problem. Extensions to higher dimensional bifurcation problems will also be presented.

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CP08
The Hamiltonian and Lagrangian Approaches to the Dynamics of Nonholonomic Systems

There are many differences in the approaches and each has its own advantages; the momentum equation and the reconstruction equation was first found on the Lagrangian side while the failure of the reduced two form to be closed was first noticed on the Hamiltonian side. Clarifying the relation between these approaches is important for developing the control, stability and bifurcation theory for such systems.

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CP08
Instabilities and Degeneracies of the 4-Dimensional Stochastic Web

We discover a fundamental mechanism for the sharp increase in the diffusion rate of the motion of a charged particle in a uniform magnetic field when a transversely propagating time-periodic electric-field is slightly tilted. It is associated with the degeneracies of the underlying motion; in fact, a two-degree of freedom mechanism of instability induces this behavior. Unfolding of this degeneracy enables the analysis of the separatrix splitting in some limits, giving a power-law rather than the typical exponential estimate of the splitting.

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CP08
On Smooth Hamiltonian Flows Limiting to Hyperbolic Billiards

Sufficient conditions are found so that families of smooth Hamiltonian flows limit to a billiard flow as a parameter $\epsilon \to 0$. This limit is proved to be C^1 near non-singular orbits and C^0 near singular (tangent to the billiard boundary) orbits. These results are used to prove that scattering (thus ergodic) billiards with tangent periodic orbits or tangent homoclinic orbits produce nearby Hamiltonian flows with elliptic islands. This implies that ergodicity may be lost for smooth potentials which are arbitrarily close to ergodic billiards.

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CP08
Approximation of KAM Tori and Aubry-Mather Sets by Periodic Solutions of a Perturbed Burgers' Equation

This investigation was stimulated by a series of papers by J.K. Moser, in which he regularized Mather's variational principle to obtain smooth approximations of Aubry-Mather sets. In this talk we provide an alternative way to construct approximations of invariant sets carrying quasiperiodic solutions. Our approach is demonstrated on a certain class of Hamiltonian systems with one and a half degrees of freedom by taking the Eulerian viewpoint and reducing the system to a perturbed Burger's equation with zero viscosity. Next, a viscousity term is introduced to regularize the solutions.

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CP09
Signal Masking Using Synchronized Chaos-Proof and Analysis by Perturbation Theory

Cuomo and Oppenheim (1993) adopted the concept of synchronized chaos (Pecora and Carroll, 1990) to mask weak messages. However, why and when the technique works was not clearly understood (Strogatz, 1995). Here, the problem is analyzed by mathematically studying the weak (integral) properties of Lorenz equations and by applying the regular perturbation theory. Finally, numerical implementation is used to verify the mathematical results.

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CP09
New Bifurcations from an Invariant Subspace

Synchronisation problems give rise to chaotic dynamics in invariant subspaces. Many simple models which attempt to understand these problems involve only one direction which is normal to the invariant subspace. We consider different phenomena which can occur in systems with particular types of symmetry and when there are two normal

directions. The theory is illustrated by some examples.

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CP09
Determining Coupling that Guarantees Synchronization between Identical Chaotic System Method

We present a criteria for determining nontrivial coupling strengths that are guaranteed to produce synchronization between chaotic systems with drive response coupling. The criteria is based on a linear analysis of perturbations. When it is satisfied one is guaranteed that small perturbations away from synchronization exponentially decay with time. The criteria is simple to use, has a simple geometric interpretation, and most calculations can be performed analytically.

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CP09
Automatic Gain Control using Synchronized Chaos

The discovery of synchronization has suggested using chaotic waveforms for communications. Practically, channel imperfections may distort the transmitted waveform and degrade communications. Specifically, exact synchronization requires unity gain in the channel when the driven subsystem is nonlinear. In this presentation, an approach for automatic gain control using synchronized chaos is reported. This approach uses cascaded subsystems to sense synchronization quality, auxiliary states to track error sensitivity to channel gain, and adaptive gain to compensate for channel losses.

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CP09
Stick-Slip Dynamics as an Elastic Excitable Media

We demonstrate the equivalence of the Burridge–Knopoff model with asymptotically viscous friction to a van der Pol–FitzHugh–Nagumo model for excitable media with elastic couplings. The proposed lubricated creep–slip friction law is appropriate to a range of real materials, and the observed dominance of low dimensional structures in our model is consistent with the results of some laboratory friction experiments. Other media such as active optical waveguides or electronic transmission lines may have similar dynamics. Our studies also predict the existence of stable global oscillations bifurcating via period doubling into space-time configurations composed of a set of spontaneous front emitting pacemakers.

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CP09
On Generalized Synchronization of Chaos in Mutually Coupled Systems

The term Generalized Synchronization of Chaos (GSC) refers to the regime where chaos synchronization occurs between systems with distinctly different individual chaotic behaviors. Although the methods for observation of GSC were originally developed only for drive-response systems, we show that some of these methods can be extended and applied to certain cases of GSC in systems with mutual coupling. In this report we present a few examples of GSC in mutually coupled chaotic systems.

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CP10
Crisis in Quasiperiodically Forced Systems

We study various types of crisis in quasiperiodically forced systems connected with the appearance of strange nonchaotic attractors (SNA), *i.e.* nonchaotic attractors with a strange geometrical structure. The quasiperiodic force leads to different bifurcations of SNA like band-merging and interior crisis which were up to now only known for chaotic attractors. These bifurcations can be identified by means of rational approximations of the quasiperiodic force and the sensitivity with respect to the external phase.

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CP10
Fractal Dimensions of Chaotic Saddles of Dynamical Systems

Formulas for the information dimensions of the natural measures of a nonattracting chaotic set and of its stable and unstable manifolds are derived in an idealized setting and conjectured to hold for invertible dynamical systems of arbitrary dimensionality. The formulas give the information dimensions in terms of the Lyapunov exponents and the decay time of the associated chaotic transient. As an example, the formulas are applied to the situation of

filtering of data from chaotic systems.

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CP10
Which Dimension of Fractal Measures are Preserved by Typival Projections?

Does the dimension of an attractor reconstructed in a low-dimensional embedding space equal the dimension of the attractor in its true state space? We show for the dimension spectrum D_q that under reasonable hyposeses the answer is "yes" for $1 < q \geq 2$ but we show by example that answer may be "no" for $q < 1$ and $q > 2$. We present and use a new definition of D_q for $q > 1$ which is equivalent to previous definitions

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CP10
Nondifferentiable Attractors, Data Filtering, and Fractal Dimension Increase

The long standing problem of why certain time-series filters (e.g. LTI or low-pass) can increase the fractal dimension of the reconstructed attractor has been solved. There is a close relation to the situation of driving a stable system with a chaotic signal as in studies of chaotic synchronization. In this talk we show that both filtering and chaotic driving can lead to an attractor in which the map from the chaotic driving system to the response system is non-differentiable (leading to a fractal object). We show how this can be detected in time-series using recently developed statistics which test for continuity and/or differentiability between reconstructed attractors.

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CP10
Determining General Fractal Dimensions from Small Data Sets

Fractal geometry is applied in many scientific fields. Even the fundamental task of estimating fractal dimensions from experimental samples suffers biases from the finite size of data sets. I discuss the application of a novel method of unbiasedly determining generalised dimensions from data sets. Example data is generated from the Henon map and obtained from plant and crab distributions. The method generally appears unbiased, reliable and provides reasonable error estimates, but currently takes $O(1000N^2)$ computer operations. This approach will be especially useful in the discernment and estimation of fractal properties from "small" data sets.

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CP10
Invariant Graphs And Strange Nonchaotic Attractors for Quasiperiodically Forced Systems

It is an open problem whether strange nonchaotic attractors can be the graph of a non-smooth function. We show that this only occurs if the closure of the attractor contains unstable orbits. More precisely we prove that if the attractor has an open neighbourhood in which all orbits have negative Liapunov exponents, then the attractor is a smooth invariant circle. We discuss the relevance of this to the creation of strange nonchaotic attractors.

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CP10
Blowout Bifurcation Route to Strange Nonchaotic Attractors

Strange nonchaotic attractors are attractors that are geometrically strange, but have nonpositive Lyapunov exponents. We show that for dynamical systems with an invariant subspace in which there is a quasiperiodic attractor, the loss of the transverse stability of the attractor can lead to the birth of a strange nonchaotic attractor. A physical phenomenon accompanying this route to strange nonchaotic attractors is a distinct type of on-off intermittent behavior.

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CP11
A Nonlinear Wave Equation Arising in Two-Phase Flow

We present and analyze a two-dimensional nonlinear wave equation derived from the Navier-Stokes equations for two miscible fluids in the limit of small Froude number. It represents a perturbation of the KdV equation and contains all low-order terms; the core part consists of the modified Kawahara equation. We look for plane solitary waves and investigate the existence and stability of one- and two-dimensional periodic solutions utilizing a Ginzburg-Landau approach. With regard to our main application, fluidized beds, the equation is able to mimick the bifurcation sequence of the original system but fails to capture the higher-amplitude behavior.

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CP11
Recent Progress in Multi-Dimensional Mode Conversion

We consider the short wavelength asymptotics of N-component wave equations in weakly nonuniform media: $\sum_{j=1}^{N} \int d^m x' D_{ij}(x,x')\psi_j(x') = 0$; with $i,j = 1,2\dots N$. Here, $x = (\mathbf{x}, t)$ with $\mathbf{x}$ an $m-1$-dimensional set of spatial variables. Two (or more) polarizations may become degenerate for some values of x and k (the conjugate wavenumber) leading to a breakdown of the WKB approximation locally in the ray phase space. New local asymptotic expansions must be developed, with important physical implications which will be discussed.

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CP11
A Robust Heteroclinic Cycle in an $O(2)\times Z_2$ Steady-State Mode Interaction

A structurally stable heteroclinic cycle connecting circles of fixed points of opposite parity is identified in a steady-state mode interaction with $O(2)\times Z_2$ symmetry. These fixed points correspond to equilibria in the form of zigzag (odd parity) and varicose (even parity) states. Because of the Z_2 reflection symmetry this 1 : 1 mode interaction bears certain similarities to earlier work on 2 : 1 mode interaction with O(2) symmetry. However, in the present case the cycle connects eight equilibria, four of which are selected from the circle of zigzag equilibria and four from the circle of varicose equilibria. Conditions for the existence and asymptotic stability of the cycle are determined and compared with numerical integration of the mode interaction equations.

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CP11
Local Singularities in Breaking Waves

We examine free surface wave singularities which show a violent focusing of energy. Periodic, modulated and frequency locked wave states lead to a state with fluid spikes. When the excitation of the free surface waves exceeds a well defined threshold, the waves break leading to a aperiodic state with spikes, droplet ejection and air entrainment. Return maps formed from wave height measurements lead to a low dimensional model of the dynamics. A local model of the fluid dynamics of the singularity is presented, along with a comparison with observed experimental events.

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CP11
Two–period Quasiperiodic Attractors of Weakly Nonlinear Gas Dynamics Equations

New never-breaking solutions for the 1 D weakly nonlinear equations of Gas Dynamics in a bounded domain with reflecting boundary conditions are obtained numerically. The Euler equations in this case are reduced to a Burgers-like equation with a linear integral dispersive term. Balance of nonlinearity and dispersion leads to the formation of time periodic or quasiperiodic solutions. We explore the long-time behavior of "arbitrary" initial conditions numerically. We found a family of attracting solutions. In the phase space of Fourier coefficients these attractors are represented by quasiperiodic orbits with two periods.

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CP11
The Strongly Attracting Character of Large Amplitude Nonlinear Resonant Acoustic Waves Without Shocks

A new class of fully nonlinear solutions for the 1-D Euler equations of Gas Dynamics in a bounded domain with reflecting boundaries is obtained numerically. These solutions never develop shocks (even though they carry large pressure variations) and can be characterized as large amplitude acoustic standing waves. In the infinite-dimensional space of the Fourier coefficients, the motion is quasiperiodic, confined to 2-D tori. Numerical experiments reveal the strongly attracting character of these solutions: Regardless of the initial conditions, these waves always dominate the flow after a sufficient time.

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CP12
Convergence of the Transfer Operator for Rational Maps

We prove that the transfer operator for a general class of rational maps converges exponentially fast in the supremum norm and in Hölder norms for small enough Hölder exponents to its principal eigendirection.

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CP12
An Exact Formula for the Essential Spectral Radius of the Matrix Ruelle Operator on Spaces of Hoelder

and Differentiable Vector-Functions

The essential spectral radius of the matrix Ruelle transfer operator $\mathcal{L}$, $(\mathcal{L}\Phi)(x) = \sum_{y \in f^{-1}x} \varphi(y)\Phi(y)$ on $C^{r,\alpha}$ is equal to

$$\exp \sup_{\nu \in \mathrm{Erg}} \{h_\nu + \lambda_\nu - (r+\alpha)\chi_\nu\}.$$

Here f is expanding, Erg is the set of all f-ergodic probability measures on a smooth manifold X, h_ν is the entropy of f with respect to ν,

$$\lambda_\nu = \lim_{n\to\infty} \frac{1}{n} \log \|\varphi^n(x)\| \quad \text{for} \quad \nu - \text{a.a.} \quad x \in X$$

is the largest Lyapunov-Oseledec exponent of the matrix cocycle $\varphi^n(x) = \varphi \circ f^{n-1}(x) \cdot \ldots \cdot \varphi(x)$ with respect to the measure ν, and χ_ν is the smallest Lyapunov-Oseledec exponent of the differential $Df^n(\cdot)$ with respect to the measure ν.

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CP12
On the Lax-Phillips Scattering Theory of Uniformly Hyperbolic Chaotic Dynamics

We apply Lax Phillips scattering theory to the study of discrete time chaotic dynamical systems. Specifically, an Axiom A (i.e. uniformly hyperbolic diffeomophism induces a unitary operator on the Hilbert space of functions square integrable with respect to a Gibbs measure. Here there are natural Hilbert subspaces, associated with the stable and unstable manifolds of the dynamics, which comprise incoming and outgoing subspaces;these are the building blocks of the Lax-Phillips theory. This talk characterizes the scattering operator of this system in terms of the data of the dynamical system and Gibbs measure, in particular in terms of the Ruelle operator. The Fourier transform of the scattering operator, the scattering function, is shown to be meromorphic in an annulus of the complex plane, and the poles and their residues are determined by the spectral properties of the Ruelle operator.

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CP12
Transfer Operators in Conformal Dynamics

Perron-Frobenius operators, equilibrium states, and invariant measures for conformal endomorphisms f of the Riemann sphere $\overline{\mathbb{C}}$ will be introduced and discussed. Given potential $\phi : J(f) \to \mathbb{R}$ with $P(f,\phi)$, where $J(f)$ is the Julia set of f there exists a unique equilibrium state of ϕ and the associate Perron-Frobenius operator is almost periodic. Its various stochastic and mixing properties will be discussed including the central limit theorem and the exponentia l decay of correlations. More special cases will be also explored, particularly the relationships between the Perron-Frobenius operator of parabolic and non-recurrent rational maps and the Perron-Frobenius operator of the corresponding jump transformation . There will be also outlined the applications to the problems of geometry of the Julia sets.

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CP13
Bifurcations and Instabilities in Moving Vortex Lattice

We investigate the stability of the vortex configuration in thin superconducting strips under an applied current analytically and by numerical simulations of the time-dependent Ginzburg-Landau equation. We show that the stationary vortex lattice becomes unstable with respect to long-wavelength perturbations above some critical current I_c. We find that at currents slightly exceeding I_c the vortex phase develops plastic flow, where large coherent pieces of the lattice are separated by lines of defects and slide with respect to each other (ice-floe-like motion). At elevated current a transition to elastic flow is observed. We discuss this transition in terms of a one-dimensional phase-slip phenomenon in superconducting wires with a periodically modulated temperature.

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CP13
Synchronization by Disorder in Parallel Arrays of Josephson Junctions

We present numerical evidence that spatial disorder can induce phase and frequency synchronization in parallel arrays of Josephson junctions driven by dc and/or ac current sources. Disorder - induced synchronization can occur even if the junctions are chaotic when uncoupled. We will discuss the consequences of improved synchronization on the current - voltage characteristics of an array and provide a qualitative understanding of the effect.

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CP13
Flux Creep in 2-D Josephson Junction Arrays

The phenomenology of flux creep in a 2-dimensional Josephson junction array subject to a slowly ramped magnetic field is considered. We describe the dynamical approach of the system to a critical state (the so-called Bean state), and derive an associated automaton model to understand subsequent avalanching behavior.

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CP13
Relaxation of Magnetic Knots to Minimal Braids

By using new equations for the Lorentz force associated with magnetic knots (Ricca 1996), we prove that inflexional knots (i.e. knots with a finite number of points of inflexion in isolation) are unstable and are isotoped naturally to inflexion-free knots, possibly in braid form. Further relaxation to minimal braids has interesting consequences on the minimum possible number of crossings, with an increase of lower bounds for magnetic energy.

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CP13
Geometrical Phase in Twisted Pairs used in Communication Networks

Twisted pairs are used in small communication networks to remedy the problem of interference between parallel wires carrying signals which tend to distort information by the electromagnetic fields they produce in their vicinity.The standard argument extended is that twisting helps in cancellation of fields in such a way that amounts to shielding the wires.We intend to explain how such cancellation takes place using the concept of Geometrical Phase; and therefore to place the classical point of view in this new perspective.

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CP13
Transonic Solutions for a Quantum Hydrodynamic Semiconductor Model

Quantum hydrodynamics is an emerging new field in semiconductor modeling. Mathematically, these models are dispersively regularized hydrodynamical equations coupled to a selfconsistently determined electric potential. The basic question is to understand the dispersionless semiclassical limit. In one space dimension this leads to a singularly perturbed system of ODEs with two slow manifolds corresponding to supersonic and subsonic states. The main physical interest lies in solutions connecting these states. We present analytical and numerical results for this transition problem.

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CP14
Ginzburg-Landau Equations for Hexagonal Patterns

Several interesting physico-chemical instabilities settle from a subcritical bifurcation. A center manifold reduction of balance equations leads to a new type of amplitude equations containing spatial gradient quadratic terms. Their form is generic since is based only on symmetry considerations. For the specific case of surface-tension-driven convection we will present the bifurcation diagrams (corresponding to amplitude and phase instabilities) and the associated patterns ear the onset of convection.

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CP14
Non-Potential Effects in Pattern Formation

It was shown recently that hexagonal convection patterns are described generally by non-potential amplitude equations which are not identical to standard Newell-Whitehead-Segel equations. In frame of the new non-potential equations, we reconsider the problem of pattern selection, calculate the "Busse balloon" for different kinds of periodic patterns (including nonequilateral hexagonal patterns) and investigate the propagation of fronts and domain walls between patterns. The nonlinear development of secondary instabilities is considered as well.

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CP14
Multiplication of Defects in Hexagonal Patterms

A typical object in hexagonal patterns is a penta-hepta defect, i.e. a bound state of two dislocations on different roll subsystems. For Marangoni convection, we numerically found a new type of nonlinear instability resulting in multiplying penta-hepta defects. Each act of multiplication includes creation of a new dislocation pair on the dislocation-free roll subsystem, and recombination of dislocations into two penta-hepta defects of the next generation. The long-run pattern evolution displays wavelength selection mediated by moving penta-hepta defects.

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CP14

Takens-Bogdanov Bifurcation on the Hexagonal Lattice for Double-Layer Convection

A bifurcation analysis is performed at a Takens-Bogdanov point, for solutions which are doubly periodic with respect to a hexagonal lattice. Included are the analyses of rolls, hexagons, triangles, rectangular patterns, traveling waves, twisted patchwork quilt, centrosymmetric solutions and heteroclinic orbits. The theory is applied to double-layer convection. A center manifold reduction scheme is used to convert the governing equations to six complex-valued ordinary differential equations, and Landau coefficients are computed for specific fluid parameters. Numerical results based on the amplitude equations are given.

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CP14

Patterns in Long Wavelength Convection

Transition from a spatially uniform state to a periodic pattern occurs in many applications. Using weakly nonlinear analysis the relative stability of hexagons and rolls or squares and rolls can be found. We demonstrate for an example p.d.e that, with little additional effort, the stability analysis can be extended. Our results include hexagon/rectangle transitions and the prediction that, on a domain with periodic boundary conditions, the observed pattern at onset depends on the size of the domain.

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CP14

The Takens–Bogdanov Bifurcation in Long-wave Theory

Considering anisotropic double-diffusion with fixed fluxes as a model problem, we asymptotically derive planform equations that capture the bifurcation structure around the codimension-two point at long wavelengths. The form of the equations obtained is valid for a wide range of physical systems. We investigate the simplified case where the system has Boussinesq symmetry.

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CP15

Irregular Jumping in the Perturbed Nonlinear Schrödinger Equation

Numerical studies indicate that certain solutions of the damped-forced nonlinear Schrodinger equation (NLS) exhibit irregular jumping in the time domain. The jumping behavior appears to be centered around the set of plane waves. In this talk I discuss how multi-pulse homoclinic and heteroclinic orbits can be constructed in the infinite dimensional phase space of the NLS, which explains the irregular jumping behavior. For the case of pure forcing, I also describe an involved sequence of homoclinic bifurcations.

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CP15

Existence and stability of singular heteroclinic orbits for the Ginzburg-Landau equation

The existence and stability of travelling waves of the Ginzburg-Landau equation is considered. The waves in question exist on a slow manifold in phase space and connect two stable plane waves with different wave numbers. The existence of these waves is proven via the use of the methods of geometric singular perturbation theory. Topological methods are used to prove the linear stability of the waves. The waves are shown to be nonlinearly stable in polynomially weighted spaces.

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CP15

Singularly Perturbed and Non-Local Modulation Equations

In this talk, two systems of coupled modulation equations for systems which are subject to two distinct destabilizing mechanisms are compared. In both systems, stationary periodic solutions exist under the same conditions. However, a variety of heteroclinic and homoclinic connections are found for the singularly perturbed system which do not have a counterpart in the non-local system. Thus, unlike the singularly perturbed system, the non-local system cannot describe 'localised structures'.

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CP15

An Accurate Description of Slow-Motion Dynam-

ics in Singularly Perturbed Reaction-Diffusion Systems

Metastable patterns and slow-motion dynamics are known to occur for singularly perturbed reaction-diffusion systems on finite intervals. [Carr, Pego] provided the equations of motion for such patterns in the case of a second-order equation using maximum principles, energy estimates and Sturm-Liouville theory. Here, using a different approach, equations governing the motion of patterns are derived for general reaction-diffusion systems with gradient terms under various boundary conditions.

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CP15
Multiple-Pulse Homoclinic and Periodic Orbits in Singularly Perturbed Systems

This talk will focus on finite dimensional singularly perturbed systems. Criteria for the existence of multiple-pulse homoclinic and periodic orbits are given. These orbits consist of finitely many slow segments and multiple fast excursions in between each pair of slow segments. The techniques used include a higher-order adiabatic Melinkov function, and a modified version of the Exchange Lemma. Applications to a model of resonant sloshing in a tank and to the FitzHugh-Nagumo equations will be given.

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CP15
Homotopy Classes for Stable Connections between Hamiltonian Saddle-Focus Equilibria

We study homoclinic and heteroclinic connections between Saddle-Focus equilibria in Hamiltonian systems with two degrees of freedom. For fourth order ODE's or mechanical Hamiltonian systems which have a non-negative Lagrangian density, and have two or more saddle-foci (four complex eigenvalues) which are global minima, we find a rich set of mulitbump homoclinic and heteroclinic connections which occur as local minima of an appropriate action functional. A subset of the solutions we find are also given by Devaney's generic result on Hamiltonian systems in the presence of saddle-foci, which requires a transverse intersection of stable and unstable manifolds. For our method no assumptions on the intersection of stable and unstable manifolds are made. The method is based on minimization on open classes of curve of certain topological type. These classes are defined as follows. In the case of two saddle-foci, say p_1 and p_2, one considers curves starting at p_1 or p_2 and terminating at p_1 or p_2. In between curves can wind around p_1 and p_2 which defines different topological classes of curves. The fact that one can minimize and the fact that p_1 and p_2 are saddle-foci allows use to prove that for almost every topological type (most words in $\pi_1^{\text{semi}}(\mathbf{R}^2\backslash\{p_1,p_2\})$) there exists a minimizer in the associated class, which is a local minimizer of action. The existence of these connections implies that the topological entropy of the Hamiltonian system in question is strictly positive and the systems are non-integrable.

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CP16
Mixing and Transport Rates for a Marangoni-driven Chaotic Flow

We treat the problem of a bubble moving in a viscous incompressible fluid due to the combined action of buoyancy and a temperature gradient. For some values of the parameters therein involved, perturbations of the flow lead to chaotic advection in the vicinity of the bubble. The stated problem is formulated in suitable variables as a two-dimensional perturbed time-periodic Hamiltonian system. We evaluate the phase space transport that takes place near the bubble during a period of the velocity field through the Melnikov function (or the adiabatic Melnikov function, for very large periods). To go beyond one period, we review the Topological Approximation Method developed by V.Rom-Kedar to obtain a partial classification of the heteroclinic tangles created by the intersections of the invariant manifolds of fixed points. The results depend on several parameters which are found both using analytical tools (Secondary Melnikov function) and numerical computations.

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CP16
Asymptotic Focusing of Particles in a Wake Flow

The understanding of a number of important natural phenomena, as well as the development of many technological applications, is based on an analysis of the dynamics of discrete particles, such as bubbles, drops, and solid particles, in fluid flows. In this talk, we discuss the dynamics of small, rigid, dilute spherical particles in the wake of a bluff body, under the assumption that the background flowfield is a spatially periodic array of Stuart vortices, which can be considered to be a regularization of the Kármán vortex street. We show that when inertia, measured by the dimensionless Stokes number, is small, there is an attracting slow manifold in the phase space of the particle motion. Using numerical methods to analyze the flow on the slow manifold, we provide an explanation for the unexpected "focusing effect" which has been observed in experiments. In these experiments, over a range of small enough values of the Stokes number, but not too small, glass beads injected into the wake of a bluff body tended to concentrate near the edges of the vortex structures shed by the body, thus tending to "demix" rather than mix homogeneously.

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CP16

Non-Normal Dynamics of Eddy Variance and Transport Properties in Geophysical Flows

Transient growth of synoptic scale disturbances in the atmosphere gives rise to the episodic occurrence of cyclones in midlatitude jets. This process of cyclogenesis is understood theoretically through analysis of the associated non-normal linear dynamical operator. By extension, the eddy velocity variance and statistical mean transports of heat and momentum produced by cyclone waves can be understood by solving the associated non-normal stochastic differential equation. The variance and transports are found to be concentrated in a small subspace of disturbances and the form of the disturbances primarily responsible for producing the variance and transports is found to be similarly restricted. In addition, changes in the system and boundary conditions producing the greatest change in variance and transports can be identified using extension of the theory. This permits bounds to be placed on the sensitivity of climate statistics to secular alterations in the atmospheric system and its boundary conditions. Examples of applications of the theory to atmospheric mid-latitude jets will be shown.

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CP16

Integrability and Non-Inegrability in Bubble Dynamics

It is well known that a slightly deformable spherical bubble exhibits in a quiescent potential flow an erratic motion. To explain this phenomenon it is shown that the motion of a bubble is governing by a Hamiltonian system on a sphere. The resulting equations of motion are similar to a time-dependent non-linear pendulum with a certain chaotical behavior. Using the averaging over the quick deformations the Liapunov stability of a rectilinear translation is investigated.

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CP16

Perturbation Growth in Non-Autonomous Geophysical Flows

Stability theory of time independent geophysical flows has recently been reinvigorated with the introduction of methods for analyzing transient growth of perturbations arising from the non-normality of the linearized dynamical operator associated with these systems. The methods used in the autonomous case are extended in this work to provide a theory for perturbation growth in time dependent non-normal systems. Non-normality is found to lead to unbounded growth of disturbances when the time dependence satisfies certain general conditions. The growth rate and functional form of the growing disturbance are found and related to the degree of non-normality and the form of the time dependence. An illustrative example drawn from the theory of baroclinic instability is analyzed.

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CP16

Experimental Evidence for Chaotic Scattering in a Fluid Wake

We present experimental evidence of chaotic scattering in a fluid wake. Measurements of tracer particles and dye in the stratified wake of a moving cylinder are shown to be consistent with four predictions based on simple models and direct numerical simulation: unstable periodic orbits were shadowed by tracer particles; streaklines marked by wake-delayed dye are shown to be fractal; early time-delay statistics of fluid elements interacting with the wake decayed exponentially; and finally, the fractal dimension of the wake is consistent with the dynamics of the wake, as measured by characteristic time delays and Lyapunov exponents.

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CP17

Controlling the Chaotic Logistic Map, An Undergraduate Project

Chaos control is completely presented, including targeting, stabilization, and the OGY technique in the context of the logistic map. By restricting the discussion to this one-dimensional map, all the required tools and techniques are accessible to undergraduate students. The goal is both to expose the students to recent and exciting developments in chaos theory, as well as to strengthen skills and intuition regarding the definition of chaos, finding periodic orbits, and determining stability. The presentation is in the form of the worksheet actually explored in small groups by West Point students.

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CP17

Development of a Laboratory Based Course in Nonlinear Dynamical Systems

We describe the development of a set of laboratory experiments designed as part of an interdisciplinary undergraduate course in nonlinear dynamical systems. A number of simple physical systems (mechanical and electrical), along with computer experiments are investigated during the labs to demonstrate the ideas of fixed points, bifurcations,chaos etc. The coursebook we use is Nonlinear Dynamical Systems and Chaos by S. H. Strogatz.

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CP17
UG Course at IIT Delhi on Self-Organising Dynamical Systems

The undergraduate students at IIT Delhi are selected through a very stringent national examination .At IITD we therefore have very outstanding students in their 4 year B.Tech program and the Institute being funded by the fedaral government allows a genourous computer accessability.Students complete apart from their departmental courses quite some external credits. As part of this external credit program I have floated and have been successfully running now for four semisters an undergraduate interdisciplinary course on "SELFORGANISING DYNAMICAL SYSTEMS" for B.Tech. students mainly of 3rd year. Experiences will be reported.

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CP17
Circle Homeomorphisms and Advanced Calculus

The study of circle homeomorphisms is an appropriate topic for an advanced calculus or introductory real analysis course. The ideas involved are substantial, yet often require proofs that are accessible to an advanced undergraduate. In addition, the student is exposed to a true success story in dynamical systems, namely, the role of the rotation number in determining the dynamics of a circle homeomorphism. Along the way the appearance of Cantor functions and Arnold tongues only adds to the appeal of the subject, and are well within the grasp of a junior or senior mathematics student.

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CP18
Phase Synchronization in an Array of Coupled Integrate-and-Fire Neurons with Dendritic Structure

Synchronization in an array of integrate-and-fire neurons with dendritic structure is studied using a phase-reduction technique. It is shown that for long-range excitatory interactions the system can undergo a bifurcation from a synchronous state to a state of travelling oscillatory waves. Such a transition is due to the diffusive spread of activity along the dendritic cable. The stability of the synchronous state is sensitive to the range of interactions and the natural frequency of oscillations. This could provide an alternative to axonal delays as an explanation for the tendency of visual crtex to synchronize in contrast to waves of activity observed in olfactory cortex.

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CP18
Desynchronisation of Neural Assemblies

We analyse a system of pulse-coupled integrate-and-fire neurons to identify mechanisms of desynchronisation. Bifurcations of the firing phase are used to determine the importance of pulse width, propagation delay, shunting currents, electrical synapses and dendritic structure for the case in which all neurons fire with the same frequency. In contrast to a model lacking any one of these these simple biological features, stable asynchronous behaviour is easily established for reciprocal excitatory coupling between neurons.

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CP18
Post-Fertilization Traveling Waves on Eggs

We consider the one-dimensional model proposed by Lane, Murray and Manoranjan to describe the propagation of a wave of calcium, and a pulse of elastic deformation, observed on the surface of some vertebrate eggs shortly after fertilization. We study the equations with smooth nonlinearities, and prove the existence of traveling fronts, for small values of a coupling parameter, by use of the Melnikov function. We also discuss a modified version of the equations for which we can prove uniform bounds on the wave speeds, suggesting the existence of waves for all values of the coupling parameter.

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CP18
Additive Neural Networks and Periodic Patterns

We present an additive recurrent neural network with weight adjustment procedure, which is able to reproduce periodic patterns. The network has the form of a cascade of nets. The presented periodic pattern is a discrete, periodic set of vectors with coordinates ± 1. The pattern gives rise to the initial vector of weights for the weight adjustment dynamics. The weights converge to a limiting set of weights and the activation dynamics with the limiting set of weights exhibits stable periodic orbit. This stable periodic orbit exhibits the presented periodic pattern in the following sense. Every orthant in $\mathcal{R}^n$ can be described by its signature, which is an n-vector of ± 1, where we put 1 if the corresponding variable is positive in the orthant and -1 if the variable is negative in the orthant. The stable periodic orbit visits consequtively orthants whose signatures form the presented periodic pattern.

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CP18
Computational and Experimental Exploration of a Cortical Neuronal Network as a Dynamical System

A large scale model of a rat whisker barrel is reduced to a simple dynamical system while retaining the ability for both qualitative and quantitative comparison with biological data. The reduced model yields novel and quantitative physiological predictions concerning the sensitivity of barrel neurons to whisker deflection amplitude and velocity. This prediction is tested directly through in vivo extracellular recording studies examing the responses of barrel neurons in the rat.

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CP18
A Bonhoeffer van der Pol Model for Action Potential in Excitability Changing Media

A simple Bonhoeffer-van der Pol model of a heart tissue is studied to find the influence of spatial changes of excitability on action potential propagation.
The velocity of propagation is shown to be a good measure of excitability for the model.
Numerical solutions are obtained for "normal" and "pathological" situations. A piecewise linear analytical model is used for perturbation treatment.

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CP19
Suppressed and Induced Chaos by Near Resonant Perturbation of Bifurcations

We present experimental results which demonstrate for the first time that the onset of chaos in a nonlinear system can be either suppressed or induced by the application of a perturbation signal which is near-resonant to a subharmonic of the fundamental system frequency. The technique represents a feedback independent method for stabilizing or destabilizing chaotic orbits. Shifts in the onset of chaos are demonstrated for perturbation signals which are near-resonant to the period-2 orbit and the period-4 orbit of the experimental system.

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CP19
Exponentially Amplified Sampling and Reconstruction of Weak Signals Using Controlled Chaotic Orbits

We describe a method of sampling and reconstructing extremely weak signals based upon fundamental properties of chaotic dynamics. We show that small, continuous-time disturbance signals coupled into a chaotic system can be reconstructed from the discrete-time perturbations required to maintain a controlled periodic orbit. We derive a scaling function necessary to transform the control perturbation sequence into the continuous-time, weak disturbance signal for a typical, dissipative chaotic system. We show experimental measurements supporting our assertions.

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CP19
Targeting from a Chaotic Scattering

We consider a model of a Hamiltonian system with an orbit "parked" on an unstable periodic orbit embedded in

an unstable chaotic set. We then attempt by means of a small control to target a position outside the original chaotic invariant set. This work illustrates how this can be accomplished using the example of the chaotic scattering set resulting from billiard type motion in the presence of three hard circular discs.

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CP19
Nonlinear Control of Remote Unstable States in a Liquid Bridge Convection Experiment

We demonstrate the stabilization of an unstable periodic orbit whose trajectory in phase space is distant from the unperturbed dynamics (characterized by two frequencies) in a convective flow experiment (Research supported by NASA and ONR). The system is a liquid bridge composed of silicone oil with a Prandtl number of about 40. Temperature is measured at a point near the free surface of the liquid column, and control perturbations are applied with a thermoelectric element located on the opposite side of the bridge from the temperature sensor. A model independent, nonlinear control algorithm uses a time series reconstruction of a control surface to characterize the system dynamics (V. Petrov and K. Showalter, Phys. Rev. Lett. 76, 3312 (1996)). Large perturbations are required to capture the targeted periodic orbit, but once captured, control can be maintained indefinitely with very small perturbations (V. Petrov et al. submitted to Phys. Rev. Lett.).

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CP19
Sustaining Chaos using Basin Boundary Saddles

We present a general method for preserving chaos in non-chaotic parameter regimes by using the natural dynamics of system, and apply it to a CO_2 laser model. Chaos is preserved by redirecting the flow towards the chaotic region along unstable manifolds of basin boundary saddles, with the use of small infrequent parameter perturbations.

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CP20
Dynamics of Two Mutually Coupled Slow Inhibitory Neurons

Recent analytic and numerical works have counter-intuitively suggested that a network of neurons connected by slow inhibitory synapses may synchronize. We present rigorous analytic results on how and under what conditions two such neurons can display stable synchronous oscillations. We show that there are two combinations of parameters that affect stability. In different parameter regimes, only one combination or the other is relevant. Thus a change of parameter that moves the system from one regime to the other changes which system parameters determine stability. Heuristic arguments for the existence of more complicated anti-phase, suppressed and n to m solutions are given.

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CP20
Weakly Connected Weakly Forced Oscillatory Neural Networks

A network of weakly connected oscillatory neurons is partitioned into pools of oscillators having similar frequencies. Neurons within a pool interact via phase deviations. Averaging shows that interactions between pools are functionally insignificant even when there are synaptic connections between them. A neuron can participate in various pools by changing its center frequency. Interactions between pools with frequencies $\Omega_1 \neq \Omega_2$ can be revived if the weak forcing is resonant with $\Omega_1 - \Omega_2$. Possible applications to thalamo-cortical interactions are discussed.

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CP20
Monitoring Changing Dynamics with Correlation Integrals: Case Study of an Epileptic Seizure

We describe a procedure, and the motivation behind it, which rapidly and accurately tracks the onset and progress of an epileptic seizure. Roughly speaking one monitors changes in the relative dispersion of a re-embedded time series. The results are robust with respect to variation of adjustable parameters such as embedding dimension, lag time, and critical distances. Moreover, the general method is virtually unaffected when the data is significantly corrupted by noise.

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CP20
Preservation and Annihilation of Colliding Pulses in a Model Excitable System

We analyze the transition from annihilation to preservation of colliding waves in a one-dimensional model excitable medium. The analysis exploits the similarity between the local and global phase portraits of the system. The transition is an infinite-dimensional analog of the creation and annihilation of limit cycles in the plane via a homoclinic Andronov bifurcation, and has parallels to the nucleation

theory of first-order phase transitions.

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CP20
Nonequilibrium Response Spectroscopy of ION Channel Gating

We describe a new electrophysiological technique called nonequilibrium response spectroscopy which involves application of a rapidly fluctuation (up to 10 kHz) large amplitude voltage clamp to voltage dependent biomolecules. The response of the channel to a rapidly fluctuating field is exquisitely sensitive to features of the gating kinetics which are difficult or impossible to adequately resolve by means of traditional stepped potential protocols. Here we focus on the application of dichotomous noise voltage fluctuations. Dichotomous noise is a broad band Markovian colored noise with a discrete state space. Since Markovian kinetic models of channel gating can be imbedded in a higher dimensional state space which takes into account the effects of the voltage fluctuations, many features of the response of the channels can be calculated in closed form. This makes dichotomous noise and is generalization uniquely suitable for model selection and kinetic analysis. While nonequilibrium response methods can be applied to gating and single channel current recording techniques, here we focus on application of this method to whole cell ionic current measurements. We show how data from the rat brain, and human cardiac isoforms of the sodium channel expressed in mammalian cells can be acquired and analyzed, and how this data reveals new, previously hidden aspect of the kinetics of these channels.

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CP20
Hodgkin-Huxley Neuronal Models

We analyze the applicability of Hodgkin-Huxley type conductance-based models of neurons, addressing the questions of parameter estimation, system noise, and model performance. Different experimental protocols and mathematical procedures for obtaining good parameter estimates are discussed, and the quality of the parameter estimation is examined in view of the inherent system noise. Finally, performance criteria for the models are considered.

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CP21
Synchronized Chaos in Spatially Extended Systems And Interhemispheric Teleconnections

Partial chaotic synchronization in extended systems is demonstrated by considering the coupling of the northern and southern hemisphere atmospheric circulations, modeled through a spectral truncation of the barotropic vorticity equation. Despite time delays in the coupling, the attractive properties of an invariant synchronization manifold in phase space cause correlations between weather regimes in the two hemispheres, though the regime transitions in each hemisphere are timed chaotically. The truncated model results agree with atmospheric observations.

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CP21
Spontaneous Synchronization and Critical Behavior in Oscillator Chains

The ability of an ensemble of disparate coupled nonlinear oscillators to spontaneously synchronize is dependent on the range and strength of interactions. This dependence is examined by introducing coupling that decays with distance as $r^{-\alpha}$ to a one dimensional chain of phase oscillators. Critical behavior is found to exist as the range of interactions is varied. Previously studied models and results are recovered in the appropriate limits.

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CP21
Synchronization and Relaxation in Globally Coupled Oscillators

We examine a class of coupled Hamiltonian systems in which identical nonlinear oscillators are coupled through a mean field. It is shown that the system has a steady desynchronized solution which becomes linearly unstable as the strength of the coupling is increased. In the stable case we observe that the order parameter of the system decays to zero. Our system shares many similarities to the Vlasov-Poisson equation and to Kuramoto's model. We apply this model to understand sound propagation in bubbly fluids.

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CP21
Synchronization of Spatiotemporal Chaos

Frequently, when chaotic systems are coupled, the complexity and the dimension of the resulting attractor increases. If however chaotic oscillations in these systems are synchronized, the dimension can remain unchanged. The simplest form of synchronized chaos is identical oscillations in coupled systems. We demonstrate that such behavior is possible even if each uncoupled system demonstrates spatiotemporal chaos. We discuss some stability issues. As an example, we consider two complex Ginzburg-Landau systems coupled dissipatively.

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CP21
Effect of Finite Inertia in Coupled Oscillator Systems

We analyze the collective behavior of a set of coupled damped driven pendula. In the limit with no inertia, this model becomes the Kuramoto model which exhibits synchronization onset by a second order phase transition without hysteresis. For the case with finite (non-small) inertia, we show that the synchronization of the oscillators exhibits a first order phase transition synchronization onset (a discontinuous jump). There is also hysteresis between two macroscopic states, a weakly and a strongly coherent synchronized state, depending on the coupling and the initial state of the oscillators. A self-consistent theory is shown to determine these cooperative phenomena and to predict the observed numerical data in specific examples.

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CP21
Coupling Topology and Global Dynamics

One of assumptions underpinning much existing work on large, coupled, dynamical systems is that the coupling topology takes a simple form: usually either mean-field or nearest-neighbour coupling. Using graph-theoretic techniques, we investigate the effects of a range of coupling topologies, exhibiting varying degrees of randomness, on the global dynamics of some commonly studied oscillator systems. Our results indicate that the global dynamical properties of some systems are highly sensitive to the underlying topology and others, not at all.

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CP22
The Melnikov Vector as an Estimate for Exponentially Small Splitting of Homoclinic Manifolds

The Melnikov vector gives an estimate of the splitting distance between invariant manifolds for an oscillatory perturbation of an integrable system in n-dimensions. When the forcing is fast (*i.e.* the period of the forcing is proportional to the perturbation istelf), the splitting distance becomes exponentially small and the use of the Melnikov vector as an estimate of the splitting distance cannot be justified. However, in many examples, conditions on the perturbations parameters can be derived so that the Melnikov vector is a correct estimate. In this talk, general necessary conditions on the parameters so that the Melnikov vector provides a valid estimate of the splitting distance are derived. To do so, the relationship between the Melnikov vector and the singularities of the solutions in complex time is analyzed in detail so that the Melnikov vector can be computed also for complex time.

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CP22
Asymptotic Expansions for Melnikov Functions for Conservative Systems

We use Melnikov techniques to show chaos without an explicit homoclinic solution. For one degree of freedom conservative equations we infer the existence of a homoclinic solution from the potential. We add perturbations: linear damping and periodic forcing, yielding two Melnikov integrals obtained without explicit knowledge of the homoclinic solution, one integral as a formula asymptotic in terms of the forcing frequency. As an example we consider a sliding mass restrained by a transverse spring.

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CP22
Calculating Chaotic Strength

The dynamics of the phase-locked loop (PLL) are both rich and complex. Using Melnikov techniques, we present a new method of driving the PLL chaotically, superior in efficiency to previously reported results. Moreover, we show how the same techniques can be used to identify the optimum excitation required to disrupt **any** weakly perturbed Hamiltonian system containing a homoclinic connection. Our analytic work is confirmed both experimentally and numerically. We close the talk with the discovery of a fascinating period-adding phenomenum in the driven PLL.

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CP22
Resonance Capture In Weakly Forced Mechanical Systems

We study capture into resonance in the spin-up of an unbalanced rotor, with two orthogonal, linearly elastic supports. As the angular velocity of the rotor approaches the natural frequencies of the frame, resonance capture may occur. Using the method of averaging, we obtain a simplified system valid in the neighborhood of the resonance. The resulting dynamical equations, which characterize capture into and escape from resonance, are studied using a generalized Melnikov integral.

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CP22

Melnikov's Method for Stochastic Multi-Degree of Freedom Dynamical Systems – Theory and Applications

Melnikov's method for finding necessary conditions for homoclinic chaos is extended to stochastically forced multi-degree of freedom dynamical systems. The stochastic Melnikov process is derived formally by generalizing results from single degree of freedom stochastic systems, and new concepts inherent in this generalization are addressed. Applications to the dynamics of a stochastically forced buckled column are presented. The use of the Melnikov process as an estimator of mean exit rates from preferred regions of phase space is investigated.

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CP22

The Melnikov Theory for Subharmonics and Their Bifurcations in Forced Oscillations

The subharmonic Melnikov theory for periodic perturbations of planar Hamiltonian systems is improved. An approximation to the associated Poincaré map in action-angle coordinates is explicitly constructed, and existence, stability and bifurcation theorems for subharmonics are obtained. In particular, simple formulas for determining the stability of subharmonics and invariant circles bifurcating from them at Hopf bifurcations are obtained. Several examples are given to illustrate our theory.

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CP23

Delaying the Transition to the Active Phase in Bursting Oscillators

In a general model for bursting oscillators, we examine the transition between the quiescent and active phases. Bursting oscillations are usually thought of as sharply turning on or off as a parameter is modified; in β-pancreas cells this describes the change in the insulin release rate as a function of the glucose concentration. Our analysis shows that there is a smooth, albeit quick, transition. Specifically, for a critical tuning of the parameters, the system trajectory remains along an unstable manifold delaying the onset of bursting.

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CP23

Bifurcations in One Model of the Bray-Liebhafsky Oscillations

We consider a system of two ordinary differential equations describing oscillations in the, so-called, Bray-Liebhafsky reaction that is much less studied than the well-known Belousov-Zhabotinsky reaction. It is shown how oscillations appear through a Hopf bifurcation and disappear through a homoclinic bifurcation. This work complements the results previously published by Noyes, Field and Kalachev (1995).

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CP23

Effect of Weak Coupling on Oscillations in Bursting Systems

We perform a bifurcation study of the Ginzburg-Landau equations to examine the interaction of a pair of coupled biological oscillators. Coupling is weak, diffusive and non-scalar, and non-identical oscillators are permitted. Our motivation is to understand the synchronization of bursting electrical activity in pancreatic β-cells. For models of the fast oscillations in bursting activity, we demonstrate the ubiquity of stable, asymmetrically phase-locked solutions, in accordance with recent experimental results.

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CP23

Interpretation of Chaos in the Belousov-Zhabotinsky Reaction

The Belousov-Zhabotinsky reaction is a chemical system that exhibits essentially all behaviors associated with nonlinear dynamic laws, e.g., oscillations, spatial patterns, excitability and chaos, as well as bifurcations among these behaviors. The chemistry of this reaction is well-enough understood that an excellent approximation to its dynamic law can be formulated. We will discuss the experimentally observed chaos in this system as well as its dynamical interpretation.

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CP23

Phase-locking and Chaos in Forced Excitable Systems

Periodically-forced excitable systems are mathematical models for a variety of important systems in physiology, including cardiac tissue, sensory systems, calcium dynam-

ics, and secretory systems. Sufficiently slow forcing leads to set-valued circle maps, but rotation numbers can be defined as in the smooth invertible case. However a different approach is needed for rapidly-varying (e.g piecewise constant) forcing. In this talk we describe recent results for a piecewise-linear Fitzhugh-Nagumo type model. In particular, we show the existence of subharmonic solutions and that stable periodic solutions with different rotation numbers coexist on open sets in parameter space (Xie, *et al.*, 1996). The latter result shows how an experimental observation first due to Mines (1913) can be understood in the context of a flow. We also show that chaotic dynamics can occur in some regions of parameter space.

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CP23
Slow Subsystem Bifurcations in Systems Exhibiting Bursting

Many models of excitable cells exhibit bistability between fast subsystem equilibria and fast subsystem periodic solutions. Depending on parameter values, such systems can exhibit bursting oscillations where fast variables (membrane potential) alternate between oscillatory and non-oscillatory states on a slow time. It will be shown, that as (slow) parameters are varied, the solutions of a polynomial model exhibiting bursting undergoes a series of bifurcations. Singular perturbation techniques and Melnikov theory will be used to split a two parameter space into regions where the model exhibits bursting and steady behavior, continual spiking and other more complicated oscillations.

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CP23
Synchronous Bursting in Coupled Neurons

The effects related to the influence of couplings on the oscillatory frequency of interacting neurons are investigated in the context of general properties inherent in different models. The effects similar to those observed in the Hindmarsh–Rose (HR) model (H.D.I. Abarbanel *et al.*, Neural Computation **8**, 1996, 234–244) are found for a broad class of models. It is shown, in particular, that the stepwise dependence of frequency on the value of inhibitory coupling occurs both at mutual synchronization of two neurons each of which is described by the same model (HM, Sherman–Rinzel, Chay) and at interaction of the neurons described by different models (Sherman–Rinzel and Chay models).

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CP24
Fronts Between Rolls of Different Wavenumbers in the Presence of Broken Reflection Symmetry

A nonvariational Ginzburg-Landau equation with quintic and space-dependent cubic terms is investigated. It is found that small terms breaking the space-reflection symmetry permit the existence of stationary fronts between roll solutions of different wavenumbers, and allow unstable roll states to invade stable ones, in contrast to both the symmetric and variational cases.

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CP24
Defects and Domain Walls in the 2D Complex Ginzburg-Landau Equation

We look at the spiral-wave domains which appear spontaneously in the complex Ginzburg-Landau equation. The domains are separated by thin walls, forming cellular patterns on length scales much larger than the basic wavelength. To good approximation, the walls are segments of hyperbolae, with a transverse structure which depends on the angle they make with the phase contours. This structure is analyzed by treating the walls as heteroclinic connections of a system of ODEs.

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CP24
Coupled Oscillators in Fluid Mechanics: Wakes behind Rows of Cylinders

The well-known Bénard-Von Kármán cylinder wake is one of the simplest oscillators of fluid mechanics. We present here the results of experimental and theoretical works devoted to coupled wakes of several cylinders placed side by side in a row perpendicular to an incoming flow. First, the coupled wakes of a pair of cylinders are investigated and in particular the occurence of the different locked and unlocked regimes, depending on the distance separating the cylinders. This study is then extended to a large number of wakes which can be modelled by a discrete complex Ginzburg-Landau equation. As predicted by a stability analysis of this model, an "optical mode" of vortex shedding, with neighbours in antiphase, is observed for weakly coupled wakes. At medium coupling, some space-time chaos is visualized. Space-time dislocations associated with wakes extinctions are randomly generated. Finally, when the distance between the cylinders is small, the wakes merge into different cells and are locked in phase in an "acoustic mode".

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CP24
Dynamics of a 2-Dimensional Complex Ginzburg Landau Equation with Chiral Symmetry Breaking

We examine numerically and analytically the effect of adding a chiral symmetry breaking term to the 2-D Complex Ginzburg Landau equation. We find the shift in the spiral wave frequency due to the addition of this term. The sign of this shift depends on the topological charge of the spiral wave. This results in the domination of one type of charge over the other - a feature seen in a recent experiment on Rayleigh-Benard convection.

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CP24
Noise Sensitivity and Boundary Effects in Travelling Wave Instabilities

We consider the dynamics of nonlinear waves in driven dissipative systems in finite domains, when the waves travel preferentially in one direction. Only when there is absolute instability can the waves sustain themselves without forcing against dissipation at the boundary; however, even in the convective regime large amplitude solutions can occur due to very small stochastic perturbations. We describe these effects for the CLG equation and a related system modelling dynamo waves in the Sun.

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CP24
Vortex Dynamics in Dissipative Systems

We derive the exact equation of motion for a vortex in two- and three-dimensional non-relativistic systems governed by the Ginzburg-Landau equation with complex coefficients. The velocity is given in terms of local gradients of the magnitude and phase of the complex field and is exact also for arbitrarily small inter-vortex distances.

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CP24
Convective and Absolute Instability in Finite Containers

We consider the effect of including realistic boundary conditions on the solutions to nonlinear equations that admit *unidirectional* waves with a definite (non-zero) group velocity. As examples we present solutions to the Complex Ginzburg-Landau equation and some simplified dynamo equations (which are used to describe the generation of magnetic fields in many astrophysical bodies). Linear theory yields solutions that resemble wall-modes. However as the control parameter is increased solutions begin to fill the domain, until the nearly uniform wave-train becomes unstable in a secondary bifurcation. Both the linear and nonlinear instabilities are related to solutions becoming *absolutely unstable*. Ideas for further applications of the theory will also be presented.

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CP25
Noise-Enhanced Information Transmission in a Network of Globally Coupled Oscillators

We demonstrate a novel form of information transmission produced by modulating the coupling strength between individual elements in a system of globally coupled nonlinear oscillators. The modulation varies the fraction of oscillators that are synchronized and transmits information through the temporal behavior of the center of mass of the system. Optimum information transmission occurs at the level of intrinsic oscillator noise that poises the system at the boundary between synchronous and non-synchronous states.

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CP25
Stochastic Resonance in a Neuronal Network from Mammalian Brain

Stochastic Resonance (SR), a phenomenon whereby random noise optimizes a system's response to an otherwise

subthreshold signal, has been postulated to provide a role for noise in information processing in the brain. We used a time varying electric field to deliver both signal and noise directly to a neuronal network from mammalian brain. As the noise amplitude was increased, we observed resonance between the network's behavior and a subthreshold signal, a clear demonstration of SR.

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CP25
Spatiotemporal Stochastic Resonance in Coupled Circuits

We show experimentally that the signal-to-noise ratio of a bistable system driven by a period signal plus noise can be significantly enhanced by diffusively coupling it into an array of similar systems. In a system comprised of up to 32 diode resonator circuits, we demonstrate that the SNR goes through a maximum as either the coupling strength or noise level is varied, and that this maximum coincides with the spatiotemporal synchronization of the lattice. In addition, a qualitative connection is confirmed between kink/antikink nucleation and the enhanced SNR.

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CP25
Coherence Resonance in a Noise-Driven Excitable System

We study the dynamics of the excitable Fitz Hugh – Nagumo system under external noisy driving. Noise activates the system producing a sequence of pulses. The coherence of these noise-induced oscillations is shown to be maximal for a certain noise amplitude. This new effect of coherence resonance is explained by different noise-dependencies of the activation and the excursion times. A simple one-dimensional model based on the Langevin dynamics is proposed for the quantitative description of this phenomenon.

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CP25
Spatiotemporal Stochastic Resonance in a System of Coupled Diode Resonators

Recently, the phenomenon of *array enhanced stochastic resonance* was demonstrated via numerical simulations by Lindner et al. [Phys. Rev. Lett. **75**, 3 (1995)]. We present experimental evidence that the signal-to-noise ratio (SNR) of the output signal of a single diode resonator can be significantly improved by coupling it diffusively into an array of up to 32 non-identical resonators. It is shown that the maximum SNR coincides with optimal spatiotemporal synchronization of the chain. We investigate the effects of different boundary conditions, and briefly address the connection between spatiotemporal stochastic resonance and the presence of kink-antikink pairs in the array.

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CP25
Spatio–Temporal Stochastic Resonance of a Kink Motion in an Inhomogeneous ϕ^4 Model

We study propagation of a kink in a ϕ^4 model with a double-well shaped inhomogeneity perturbed by noise. Due to inhomogeneity, the kink perfomes stochastic motion which is closely akin to the Brownian motion of a particle in a double-well potential. With small periodic force applied to the system we observed stochastic resonance in the motion of the kink: at an optimal noise level the hopping dynamics of the kink becomes most coherent and the response of the system to the periodic force is maximum. Theoretical results obtained by means of a perturbation theory are supported by the direct numerical simulations of the partial differential equations of the model.

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CP26
Wave Propagation and its Failure in a Discrete Reaction-Diffusion Equation

We construct exact travelling wave solutions of a discrete reaction-diffusion equation describing a system of coupled bistable elements. The form of the bistable potential is chosen such that in a moving frame the waveform satisfies an integrable discrete equation that can be solved explicitly. We analyse the linear stability of the wave and study wave propagation failure in the case of weak coupling using the anti-integrable limit. We also discuss some other applications of the anti-integrable limit in studying the behaviour of nonlinear discrete systems including the formation of localized states in a self-organizing neural network and localized breathers in the nonlinear discrete Schrödinger equation.

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CP26

The Evolution of Slow Dispersal Rates: A Reaction Diffusion System

We consider n phenotypes of a species in continuous but heterogeneous environment. It is assumed that the phenotypes differ only in their diffusion rates. Assuming haploid genetics and a small rate of mutation it is shown that the only nontrivial equilibrium is a population dominated by the slowest diffusing phenotype. We, also, prove that if there are only two possible phenotypes then this equilibrium is a global attractor and conjecture that this is true in general. Numerical simulations supporting this conjecture and suggesting this is a robust phenomena are also discussed.

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CP26

Numerical Study of Bifurcations of Traveling Wave Solutions in a Reaction-Diffusion System

We study continuation and bifurcations of connection orbits which are traveling wave solutions to the generalized FitzHugh-Nagumo equations. Our analysis includes detection of the heteroclinic loop and its continuation in 3 parameters, and searching for twisting points.

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CP26

Rhombs, Supersquares, and Pattern Competition in Reaction-Diffusion Systems

We use equivariant bifurcation theory to investigate steady, spatially-periodic solutions of a general two-variable system of reaction-diffusion equations which undergoes a Turing instability. We then apply our results to specific models, such as Lengyel and Epstein's CIMA reaction model or the Schnakenberg model, to investigate transitions between e.g. hexagonal and rhombic patterns. The general results are also used to construct models which produce "supersquare" patterns in numerical simulations.

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CP26

Transition to an Effective Medium and Traveling Waves in Heterogeneous Reaction-Diffusion Systems

Pattern formation and wave propagation is studied in composite reaction-diffusion systems with spatially varying kinetic properties in one and two spatial dimensions. Perturbation theory is used to derive front equations of motion in a two-component bistable medium, capturing effects like stationary or oscillatory front pinning with broken reflectional symmetry. Direct numerical simulations for strongly varying media show a transition to "effective medium"-behavior, with "effective" traveling waves (pulses as well as spirals), that reflect the geometric arrangement of the heterogeneities. These "effective" waves lose stability as the length scale of the heterogeneity is increased. Further insight into the spatiotemporal dynamics is obtained from stability analysis of stationary as well as periodic solutions of the PDE and by application of the Karhunen-Loeve decomposition.

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CP26

Spatial Patterns and Dynamics in Filtration Combustion

Filtration combustion refers to highly exothermic heterogeneous reactions in porous media involving both gaseous and solid reactants. The reactions are characterized by high activation energies resulting in thin reaction zones. Using analytical and numerical methods, we describe instabilities, dynamic behavior and pattern formation of propagating combustion wave solutions. The heterogeneous nature of the process allows interaction of instabilities and phenomena characteristic of solid combustion with those of gaseous combustion.

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CP27

Stability Analysis of Reaction-Diffusion Waves Near Transitions to Spatiotemporal Chaos

The stability of solitary pulses, wavetrains and fronts near the onset of spatiotemporal chaos in a two-species reaction-diffusion (RD) model in one spatial dimension is investigated within a discretized, finite box representation of the original RD model in a comoving reference frame and compared to results from direct numerical simulations. We have identified three different scenarios of pulse bifurcation: a collision of pulse branches, a saddle-node bifurcation and a Hopf bifurcation leading to modulated traveling wave so-

lutions in the PDE. In addition, stability results in two spatial dimension are presented for rotating waves in small circles (strong influence of boundary) and for the breakup of rotating spiral waves in large domains.

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CP27

Strange Attractors of the KdV-KS Equation: Spatiotemporal Order and Chaos in 3D Film Flows

We report analytic and numerical studies of a (1+2)D evolution equation (EE) approximating the surface of a film flowing down an inclined plane. The EE contains a control parameter, the dispersivity-to-dissipativity ratio λ. In (1+1)D case, the EE is the KdV one with (important) additional (dissipative) KS terms; it becomes just the KS equation for $\lambda \to 0$. We emphasize time-asymptotic regimes. Although the attractors are strange (the largest Liapunov exponents are positive) for all cases, it is only for small λ that the surface waves appear disordered: For large λ, they become unusual spatially *ordered* patterns, travelling collections of coherent soliton-like structures. Movies of these asymptotic regimes (see also http://euler.math.ua.edu:1997) will be shown. Statistical correlation results will be presented for both disordered and ordered wavy surfaces.

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CP27

Reduction of Complexity and Control of Spatio-Temporal Chaos through Archetypes

The space-time description of complex, extended systems can sometimes be reduced to a few effective degrees of freedom by archetype decomposition–a variant of principal component analysis that searches for archetypal patterns in raw data. We show that it is possible to identify low dimensional unstable periodicity in systems exhibiting spatio-temporal chaos via archetype analysis. We also demonstrate how archetype analysis can facilitate the implementation of strategies for controlling unstable periodic modes in such systems.

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CP27

Spatially Coherent States in Long Range Coupled Maps

We show that the dynamics of logistic maps with a scaling form of connectivity exhibit a transition from spatial disorder to a spatially uniform, temporally chaotic state as the scaling is varied. We show that this transition is associated with a gap in the eigenvalue spectrum of the connectivity matrix. We also study the Lyapunov spectrum of the system away from the transition.

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CP27

Detecting and Extracting Messages from Chaotic Communications using Nonlinear Dynamic Forecasting

This paper will consider the use of nonlinear dynamic forecasting to detect and extract message signals from chaotic communication systems, using additive-message, modulated-message, and chaotic control schemes. The role of one-step and multi-step predictions will be considered, and techniques will be discussed which can aid in rebuilding the hidden message signal from short multi-step predictions. Some suggestions will be made about increasing the security in chaotic communication systems.

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CP27

Local Dynamics and Spatiotemporal Complexity

We study a degenerate local bifurcation in the Brusselator reaction-diffusion equations, for which standard unfolding and analysis predicts complex behavior, including Šil'nikov chaos. However, we show that such local analysis provides only limited understanding of spatiotemporal complexity, as the normal form has very restricted validity. Our approach involves careful comparison of the predictions of computed high-order (nonunique) normal forms with the untransformed system on the center manifold, and approximations of the full PDE.

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CP28

The Dynamics of Variable Time-Stepping ODE Solvers

Most commercial IVP solvers for ODEs use variable time-stepping algorithms to minimize the work done in an integration. These numerical algorithms define discrete dynamical systems which are discontinuous due to the timestep-selection mechanism; furthermore, they are in

a phase space one dimension higher than that of the ODE itself. We study Runge-Kutta methods controlled by commonly-used timestep selection strategies and prove convergence results for trajectories on finite time intervals as the tolerance $\tau \to 0$. We also examine the existence and convergence properties of invariant limit sets for a class of discontinuous mappings that includes these numerical schemes.

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CP28

Multiple-shooting Newton-Picard Methods for Computing Periodic Solutions of Large-Scale Dynamical Systems with Low-Dimensional Dynamics

We will present a method based on multiple shooting to compute and determine the stability of both stable and unstable periodic orbits of certain classes of partial differential equations. The method uses a clever combination of a direct linear system solver and a Picard iteration to solve the linearised systems and generates good estimates for the dominant Floquet multipliers almost for free. The method is particularly interesting when a fine discretisation is needed.

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CP28

Computation of Stability Basin for Large Close-to-Hamiltonian Nonlinear Systems

It is shown that stability boundaries for multidimensional close-to-Hamiltonian models of power systems include fractal layers consisting of irregular mosaic of instable islands imbedded in stability areas. Novel computational methodology revealing transient stability phenomena occurring on short time intervals is proposed. Developed method runs much faster than the numerical simulation and provide the averaging of results obtained by numerous individual simulations.

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CP28

Reliable Numerical Detection of Chaotic Behaviour in Hamiltonian Systems

One is often interested in long-term stability of complicated Hamiltonian systems and reliably determining whether chaotic behaviour exists. For this, we require a fast numerical integration algorithm that is explicitly symplectic. Otherwise, we can get spurious chaotic behaviour where none exists. We present an efficient symplectic integration algorithm using Lie perturbation theory. We present examples where conventional numerical integration techniques lead to spurious chaotic behaviour whereas our algorithm leads to correct results.

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CP28

Convergence of a Fourier-Spline Representation of the Poincaré Map Generator

The generating function for a Poincaré map of an Hamiltonian system may be approximated as a truncated Fourier series in angle variables, the Fourier coefficients being spline functions of action variables. The coefficients may be constructed numerically from data on the underlying flow as given by a symplectic integrator. We investigate the convergence of the representation as the number of Fourier modes and the number of spline knots tend to infinity.

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CP29

Homogenization of the Navier-Stokes Equation for Oscillatory Fluids

The Navier-Stokes equation is homogenized for oscillatory fluids. This results justifies multi-scales expansions common in physics and engineering. We capture the contributions of small fluctuations to the mean flow and apply the method to prove the Kolmogorov scaling for oscillatory fluids.

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CP29

The Transition to Chaos for an Array of External Driven Vortices

We will present results on the transition from laminar flow to chaos for an array of externally driven vortices. The strength of the forcing plays the role of the bifurcation parameter. We investigate numerically the changes in the bifurcation sequence and the generation of large scale shear flows for different number, as well as different aspect ratios, of the driven vortices. The influence of stress-free and no-slip boundary conditons, will also be presented.

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CP29
Beltrami Flows and Contact Geometry

We consider the class of nonsingular Eulerian flows which are parallel to their curl: Beltrami flows. We establish a surprising connection between these flows and recent results in contact geometry. We draw an equivalence between such Beltrami flows and abstract "Reeb fields", which allows us to conclude the general existence of closed flowlines. This leads to results on hydrodynamic stability of Beltrami flows.

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CP29
The Temporal Dynamics of the Ocean Circulation

Because of dynamical constraints, the large-scale movement of water in the general circulation of the ocean is irregular but not fully turbulent. Such circulations are typically modelled numerically as high-dimensional, damped, dynamical systems (with dimension of $O(10^4 - 10^6)$). Using long-term integrations of such a model, we explore both the regime in which low-dimensional dynamics prevails and the "higher Reynolds number" regime beyond this. Simple low-dimensional models of the low-dimensional regime are presented and their limitations are discussed. The nature of the transition from low-dimensional behavior to progressively higher-dimensional behavior is described using a variety of statistical techniques. It is shown that in this transition, long-term variability is introduced with time scales that are centennial and longer. Understanding the nature of this transition is therefore an open problem of direct relevance to the study of fluctuations in the Earth's climate.

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CP29
Continuous Avalanche Mixing of Granular Solids in a Rotating Drum

We consider the avalanche mixing of a monodisperse collection of granular solids in a slowly rotating drum. A rather clever computer model of this process has been developed for the case where the drum rotates slowly enough that each avalanche ceases completely before a new one begins [METCALFE, SHINBROT, MCCARTHY, AND OTTINO, *Nature*, 374(1995)]. We develop a *mathematical* model for the mixing in both this discrete avalanche case and in the more useful case where the drum is rotated quickly enough to induce a continuous avalanche in the material but slowly enough to avoid significant inertial effects. Our discrete model yields results which are consistent with those obtained by Metcalfe *et al.*

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CP29
Granular Glasses and Fluctuating Hydrodynamics

The properties of dense granular systems are analyzed from a hydrodynamical point of view, based on conservation laws for the particle number density and linear momentum. We discuss averaging problems and the peculiarities of the sources of noise. We perform a quantitative study by combining analitical and available experimental results on creep during compaction and data from molecular dynamic simulations of convective flow. We study boundary conditions and finally show that the numerical integration of the hydrodynamic equations gives the expected evolution for the time-dependent fields.

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CP30
Global Asymptotic Behavior and Dispersion in Size-Structured, Discrete Competitive Systems

The model for this study is a 2 species discrete competitive system with two size classes, small and large. During each time period, some small ones and some large ones die, some small ones become large, and some small ones stay small. As the small ones become large, they disperse between two patches. Conditions for the global convergence to the extinction states of each of the two competing species are investigated. The relationship between the carrying capacities of the species and their persistence is also explored. Through numerical studies, we show that this model has a riddled basin of attraction.

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CP30
Population Dynamics of Dungeness Crab: Connecting Mechanistic Models to Data

We show density dependent features of Dungeness crab biology may cause large amplitude population fluctuations when subjected to small environmental perturbations. We do this by fitting a stochastic mechanistic model to time series data (42 years). The model incorporates cannibalism, density-dependent egg production, age-structure, and a realistic multivariate noise structure. The best fitting parameter values for the underlying deterministic models produce equilibrium (6 ports) and limit cycles (2 ports) in the absence of environmental perturbations.

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CP30
Pattern Formation In Vitro

Spectacular spatial patterns can be formed from the aggregation of microorganisms in an initially homogeneous environment, as they interact with each other and with their environment. Well-known examples are the chemotactic aggregation patterns of the slime mold *Dictyostelium discoideum* and the bacterium *E. coli*. We study a chemotactic model of pattern formation in cultures of *E. coli* and *Salmonella typhimurium*, and a non-chemotactic aggregating eukaryotic system which appears to generate pattern in vitro using only traction forces. Our simplest assumptions lead to experimentally observed patterns in all of these systems under a wide range of conditions. The eukaryotic system is dependent on the cells dynamically changing the material properties of their extracellular matrix.

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CP30
Bifurcation Analysis of Nephron Pressure and Flow Regulation

By regulating the secretion of salts, water and metabolic endproducts, the kidney plays an important role in controlling the blood pressure. To protect their own function and secure a relatively constant blood flow, the kidneys also dispose of mechanisms that can compensate for variations in the arterial blood pressure. One such mechanism is associated with the myogenic response of the afferent arterioles that cause these vessels to contract when the blood pressure rises. Another mechanism is associated with the so-called tubuloglomerular feedback which involves a regulation of the arteriolar flow resistence in response to the composition of the fluid leaving the loop of Henle. Each response can become unstable and produce self-sustained oscillations with characteristic periodicities. Based directly on the involved physiological mechanisms we have developed a model of these feedback regulations. It is shown how a Hopf bifurcation leads the system to perform self-sustained oscillations if the tubuloglumerular feedback gain becomes sufficiently strong, and how a further increase of this parameter produces a folded structure (crossroad area) of overlapping period-doubling cascades. The numerical analyses are supported by existing experimental results.

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CP30
A Two-Dimensional Model of Human Walking

A two-dimensional, four-angle model of human walking will be presented. The model will examine both the swing phase as well as the double support phase of gait through the use of Lagrangian equations of motion. A relaxation method scheme is employed to solve the resulting nonlinear ordinary differential equations so that the model can predict such gait characteristics as toe-off angle and step length. To conclude, animations of both experimental data and model predictions will be shown to demonstrate the model's accuracy.

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CP30
Dynamics of Mass Attack, Spatial Invasion of Pine Beetles into Lodgepole Forests

The Mountain Pine Beetle (MPB) is a major cause of destruction of valuable wood resources in the western States. A system of Partial Differential Equations (PDE) has been developed to model the spatial redistribution of the MPB. This model is based on movement of the flying MPB in response to the chemical environment and incorporates the trees natural defense mechanism of pitching out nesting MPB. Solving this system of PDE's can be computationally time consuming so a system of Integro-Difference Equations (IDE) has been developed to approximate the system of PDE's. In this talk we will compare the numerical scheme for solving both the IDE and PDE systems by looking at the dynamics they suggest for the MPB mass attack.

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CP31

Coupled Mechanical-Structural Dynamical Systems: A Geometric Singular Perturbation-Proper Orthogonal Decomposition Approach

We combine the theories of GSP(geometric singular perturbation), and POD(proper orthogonal decomposition) to study coupled infinite-dimensional dynamical systems in mechanics. We present results for a mechanical-structural system consisting of a pendulum coupled to a linear viscoelastic rod. Whenever the coupling between the flexible rod and the pendulum is sufficiently small, the GSP predicts a global, nonlinear, two-dimensional invariant manifold. The long-time(slow) dynamics reside on this manifold. The POD method confirms this result since it predicts a single coherent structure for sufficiently small coupling. Using the POD method, we identify the additional degrees-of-freedom that are activated as the coupling increases.

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CP31

The Karhunen-Loeve Transformation: When does it work?

The application of the Karhunen-Loeve (KL) procedure to the analysis of spatio-temporal data sets and models begins with computing data dependent eigenvectors which form the basis of an orthogonal transformation. This transformation produces what is often referred to as an "optimal representation" of the data. This talk will focus on when the KL procedure is actually optimal, and when it is not. We also will consider how dimensionality reducing mappings can be constructed to improve upon the KL approach when it in fact fails to be optimal.

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CP31

On Dynamical Systems Obtained Via Galerkin Projection onto Bases of KL-Eigenfunctions for Fluid Flows

In this talk we present an analysis of the application of Galerkin projection in conjunction with Karhunen-Loève eigenfunctions obtained from complex (transitional or turbulent) unsteady fluid flows. We will show that for certain cases it is possible to derive dynamical systems representations for arbitrary subregions of a flow that are *exact* in a certain sense. It will turn out, however, that these exact representations may nevertheless be only of limited use. Our discussion shows that for the projections considered here, one has to take into account the question of completeness of the set of basis functions.

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CP31

A Study of Transition in Rayleigh-Benard Convection using a Karhunen-Loeve Basis

A Karhunen-Loeve (K-L) basis is generated from a database obtained from a numerical simulation of the Boussinesq equations governing Rayleigh-Benard thermal convection in a horizontally periodic convective box bounded vertically by a free surface at some reference values of the parameters; Rayleigh number, Prandtl number and aspect ratio of the convective box. The K-L basis is then used to reduce the Boussinesq equations into a truncated system of amplitude equations, in which Rayleigh number is kept as a parameter while Prandtl number and aspect ratio are fixed at the reference values, by a Galerkin projection. This system is studied as a model of the transition as Rayleigh number is increased passed its critical value from the linear stability theory.

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CP31

Detecting Interacting Modes in Spatiotemporal Signals

A method for the analysis of spatiotemporal signals is presented. The approach aims at a decomposition of the signal $q(\mathbf{x},t) = \sum_i \xi_i(t)\mathbf{u}_i$ by the simultaneous identification of the spatial modes $\mathbf{u}_i$ and the underlying dynamical system $\partial\xi_i/\partial t = f[\{\xi_j\}]$. This is accomplished by minimizing a least-square-fit potential which yields a nonlinear eigenvalue problem with higher order correlation tensors. Applications of the algorithm to hydrodynamic instabilities [Uhl, C., Friedrich, R. , Haken, H., Phys.Rev.E **51**, 5, 3890] are presented. Medical applications are shown in a second contribution.

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CP32

Enhancement of Stirring by Chaotic Advection using Parameter Perturbation and Target Dynamics

The problem of maintaining chaotic stirring of particles advected in a fluid is treated using occasional perturbations of a system parameter and prescribed chaotic target dynamics. The symmetry of the regular motion is broken by forcing it to follow a chaotic reference model. Results of simulations are presented for a class of eggbeater models. Increasing the allowed maximum level of the control effort causes the regular motion to become chaotic in a shorter

time.

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CP32
Fractal Entrainment Sets of Tracers Advected by Chaotic Temporally irregular Fluid Flows

We model a two-dimensional open fluid flow that has temporally irregular time dependence by a random map $\xi_{n+1} = \mathbf{M}_n(\xi_n)$, where on each iterate n, the map $\mathbf{M}_n$ is chosen from an ensemble. We show that a tracer distribution advected through a chaotic region can be entrained on a set that becomes fractal as time increases. Theoretical and numerical results on the multifractal dimension spectrum are presented.

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CP32
Chaotic Advection in an Array of Quasi-2D Vortices

Chaotic advection and mixing of passive tracers in an array of quasi-2D vortices are studied by laboratory experiments in stratified fluids. The vortices result from the inverse energy cascade of quasi-2D turbulence in a rectangular container. Both the Eularian flow field and the Lagrangian motion of particles and blobs of dye are measured with digital image-analysing techniques. Numerical simulations and methods of dynamical systems theory are applied to analyse the (chaotic) transport properties of these tracers.

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CP32
Quantifying Transport in Numerical Simulations of Oceanic Flows

Geometric methods from dynamical systems are used to characterize Lagrangian transport in numerical simulations of two-dimensional, oceanic flows. Numerical methods for approximating invariant manifolds of hyperbolic fixed points are applied to the fully aperiodic, time-dependent vector fields, identifying two-dimensional "stable" and "unstable" manifolds emanating from regions of strong hyperbolicity. The lobes resulting from the transverse intersections of these invariant structures are used to quantify the transport between different regions of the flow.

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CP32
Anomalous Dispersion in 2-d Turbulence

Here I discuss some recent results on single-particle dispersion in 2D turbulence and point vortex systems. The main result is the identification of different regimes of anomalous dispersion at intermediate times, related to the dominance of hyperbolic or elliptic regions and to the presence of coherent vortices. The chaoticity of Lagrangian trajectories is studied as well. A comparison with the dispersion properties of ocean subsurface floats (SOFAR floats) is considered.

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CP32
Geometrical Dependence of Finite Time Lyapunov Exponents and Transport

We report a general relationship between finite time Lyapunov exponents and the geometry of stable foliations of low dimensional dynamical systems (Physica D **95** 283-305). In short, the finite time Lyapunov exponent varies smoothly along the stable foliation and its spatial derivative is determined by the divergence of the tangent (unit) vector of the stable foilation. Numerical illustrations will be presented for both conservative and dissipative systems. One immediate application is the prediction of a new class of barriers for diffusive transport in hamiltonian systems.

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CP33
Bifurcation Leading to Hysteresis

We study the bifurcation which leads to hysteresis in a bistable differential equation with periodic modulation of a parameter. Such equations are of interest in optical bistability and ferromagnetism. As the modulation amplitude increases, two stable and one unstable cycles join to form a hysteresis loop. We study the equation

$$x'(t) = L(x(t)) + h\mu(t),$$

where L is piecewise linear and h is amplitude. We make use of symmetry properties and of explicit solutions of the equation to study the bifurcation process and critical value of the amplitude.

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CP33

An Introduction to Groebner Bases and Invariant Theory

The problem of finding normal forms for systems with symmetry is closely related to the Nineteenth Century algebraic subject of Invariant Theory and Hilbert's Fourteenth Problem. The recent development of Groebner bases facilitates a systematic search for the invariants and the relationships among them. In addition, Groebner bases have a wide variety of applications to other problems.

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CP33

On a Neutral Functional Differential Equation Modelling a Simple Physical System

One of the simplest differential equations used to model physical systems is a damped harmonic oscillator. In certain applications If there is a time delay associated with this feedback, our "simple" model has become a neutral functional differential equation, which can be quite complicated to analyse. We will consider the stability of the trivial solution to this equation, with particular regard to the role of the time delay in thise stability. We will show that bifurcations to periodic solutions can occur and formulate conditions under which two such bifurcations may interact, leading to a codimension two bifurcation. Finally, we will show that such interactions may be resonant, i.e. that the frequencies of the associated periodic solutions, w1,w2, may obey w1:w2=m:n, where m and n are integers.

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CP33

Feedback-Assisted Instability Detection

We present a new methodology for the *experimental* study of instabilities in nonlinear dynamical systems. In contrast to the usual "settle and observe" protocol, we use feedback algorithms motivated by numerical bifurcation theory to experimentally trace bifurcation diagrams. Bifurcation points of the experiment become steady states of an augmented dynamical system in which the control parameter is considered as an additional state variable. We demonstrate the applicability of the proposed method in several cases, including convergence on "hard" bifurcations such as a subcritical Hopf. We study the issue of single state measurement versus complete state measurement as well as the effect of noise on our identification/feedback scheme.

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CP33

Instabilities of Spatio-Temporally Symmetric Periodic Orbits

We develop tools to analyse the instabilities of periodic orbits with spatio-temporal symmetries. Convection problems with periodic side boundary conditions often have temporally periodic solutions that are invariant under advancing a fraction of their temporal period combined with a reflection or rotation. Translations generate a continuous family of these solutions, and bifurcations that break the spatio-temporal symmetry can lead to solutions that drift along this group orbit. We discuss examples from magnetoconvection and other hydrodynamic systems.

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CP33

Grazing Bifurcations in a Piezoelectric Impact Oscillator

Grazing bifurcations tend to occur in non-smooth dynamical systems and are considered important physical examples of a general type of bifurcations called border-collision bifurcations. Recently, there has been a flurry of activity in numerically analyzing the Nordmark map which predicts the generic behavior of grazing bifurcations in impacting systems. In this work, an experimental investigation of grazing bifurcations in a piezoelectric impact oscillator is carried out. Experimental verification of the predictions regarding observation of "maximal" periodic orbits close to grazing impact is carried out.

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CP33

Stability of the Whirling Modes of a Hanging Chain (Kolodner's Modes)

In 1955, Kolodner proved the existence of infinitely many families of relative equilibria for the equations that model a hanging chain. The stability of these nonlinear whirling modes has remained an open problem. I prove the linear orbital stability of the relative equilibria that are sufficiently close to the vertical equilibrium (i.e. that have sufficiently small angular momentum). The proof relies on the invariance of the stable equilibrium under the action of the symmetry group $SO(2)$. The stability of Kolodner's whirling modes is an application of a more general result. Consider

a simple mechanical system (Q, K, V, G) with symmetry group $G = SO(2)$ whose action is not free, and let $\mathbf{q}_0$ be an equilibrium for which $V''(\mathbf{q}_0) > 0$. I prove (under some fairly general conditions) the linear orbital stability of all relative equilibria sufficiently close to $\mathbf{q}_0$. A finite dimensional system to which the theory applies is the double spherical pendulum.

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CP34
Testing Nonlinear Markovian Hypotheses in Dynamical Systems

We present a statistical approach for detecting the Markovian character of dynamical systems by analyzing their flow of information via higher order cumulants. As an extension of Theiler's method of surrogate data this cumulant based information flow is used as the discriminating statistic in testing the observed dynamics against a *hierarchy* of null hypotheses corresponding to *nonlinear* Markov processes of increasing order. Numerical results on nonlinear processes, autoregressive models and noisy chaos are discussed.

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CP34
Chaos and Detection

I report on numerical experiments in which chaotic signals were reliably detected at signal to noise ratios as low as -15dB. The detector was based on a variant of the hidden Markov models used in speech research. I review theoretical bounds on model performance given in terms of the Fourier power spectrum and the *KS entropy* of a chaotic system. KS entropy estimates indicate that even better detection performance is possible.

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CP34
Time-Series Analysis Tools for Nonlinear System Identification

Deriving ordinary differential equation (ODE) models of nonlinear and chaotic systems from experimental time series can be extremely difficult, particularly because classical time-series analysis methods are often inadequate when applied to these types of data sets. We have developed a set of nonlinear analysis tools that facilitate the analysis of such data, with the specific goal of elucidating differences between good and bad ODE models. In particular, we focus our efforts on leveraging these tools to derive a tter model of the driven, damped pendulum.

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CP34
No Noise is Good Noise?

Much recent activity in nonlinear signal processing theory has been directed towards the discovery and exploitation of structure in noise processes. This talk will describe ceratin exotic processes which in a very real sense may be regarded as "good noise"=97 the sense being that we have developed techniques to make a separartion - in principle an exact separation - of signals from noises in this class. The class includes deterministic, chaotic processes as well as nonlinear stochastic processes equivalent to random dynamics on a fractal set. Our interest in these is twofold: we hope, and there is some evidence to believe, that these noises are relevant to genuine applications in signal processing; more generally, we would like to know "What makes a good noise?"

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CP34
Is There a Deterministic Relation (Phase Locking) between Sunspot Cycles and Interdecadal Variability of Atmospheric Temperature?

Discrete Hilbert transform was used to obtain instantaneous phases from band-pass filtered monthly atmospheric temperature records from eight European stations (all over two hundred years long) as well as from monthly sunspot numbers. A possibility of phase locking between the sunspots and the temperatures was indicated in a few segments of the series, while phase locking between temperature records from different locations were also found in segments not locked with the sunspots.

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CP34
Takens Embedding Theorems for Forced and Stochastic Systems

Takens Embedding Theorem provides the theoretical foundation for most techniques in nonlinear time series analysis. Current versions assume that the time series is generated by an autonomous deterministic system. These conditions rarely hold in practical applications: most real systems are noisy, and even when the noise can be neglected, many deterministic systems are forced, or subject to arbitrary input signals. We describe extensions of the Embedding Theorem to cover these cases.

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CP34
Detecting Singularities of Non-deterministic Dynamics

It has been demonstrated that a non-deterministic form of chaos is possible when Lipschitz conditions at singular points are relaxed. Detection of such singularities in real life data is made difficult by the inherent limitations of digital data acquisition.We present the results of several techniques to overcome these limitations,including 1) orthogonal vectors; 2) divergent second derivatives; 3) wavelets; and 4) recurrences. Both simulated and experimental biological data, including arm motion, and ECG's are used.

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CP35
Acoustic Turbulence

We consider Kolmogorov-like spectra for the stochastic motion of a compressible fluid without vorticity. Unlike to the turbulence of incompressible fluid, the turbulence spectrum E_k for the compressible fluid can not be obtained only from the dimensional considerations, since it can depend on one more dimensional quantity — the sound speed c, in addition to the fluid's density ρ, the energy flux ε, and the wave number k. It is shown that the spectrum E_k is proportional to $\varepsilon^{2/3}$ (as for the Kolmogorov spectrum) if the dimension of the medium is 1, to $\varepsilon^{3/5}$ for 2D media, and to $\varepsilon^{1/2}$ for 3D media; then the dimensional considerations determine the other scaling exponents of the corresponding turbulence spectra. The physical implications are discussed.

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CP35
Interfacial Turbulence at Large Prandtl Number

The 3D Marangoni-Benard instability problem is studied, via reduction to a 2D model equation describing the dynamics of the free surface temperature field. The model incorporates the energy input at large length scales (primary instability), thermal dissipation at small scales, and nonlinear energy transfer from large to small scales due to the surface advection of the temperature field. Turbulent polygonal patterns are obtained as a result of the secondary instability of the thermal boundary layer occurring at large supercriticality.

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CP35
Nonlinear Dynamics of Electrochemical Oscillations, Surface Morphology and Corrosion

We studied the nonlinear dynamics of electrochemical oscillations of various "flavors" of bare,coated and ion implanted metallic samples.While the inner mechanisms of these oscillations are still far from being fully understood, the behavior of the surface and current oscillations seem to be related. We investigated the correlation between oscillations dynamics and surface morphology. This study has several important industrial applications.This project is supported by LEQSF and DOE

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CP35
Space-Time Modeling and Pattern Formation in Rotating Flows

A fluid flow enclosed in a cylindrical container where fluid motion is created by the rotation of one end wall is studied. Direct numerical simulations and spatio-temporal analysis have been performed over a broad range of Reynolds numbers. The most striking analogy with experimental results are obtained by tracking particles in time. The transition to turbulence scenario, including breakdown of axisymmetric to three-dimensional flow behavior, is addressed.

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CP35

Chaotic Transport in a Chain of Vortices: Anomalous Diffusion and Levy Statistics

Transport in a quasi-geostrophic chain of vortices in shear flow is studied using a Hamiltonian model. Particles alternate chaotically between being untrapped, and being trapped in the vortices. The probability distribution functions of trapping/untrapping events are computed and shown to exhibit power-law scaling behavior. Anomalous (non-Brownian) enhanced diffusion is observed and characterized in terms of Levy (non-Gaussian) probability distributions. The results are compared with experiments on transport in a rotating annulus (see abstract by Weeks et al.), and with continuous-time random walk models.

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CP35

Anomalous Transport in an Incompressible, Temporally Irregular Flow

We investigate the longitudinal dispersion of passive tracers in a transversely bounded, incompressible, two dimensional flow. the flow is assumed to be temporally irregular, but to possess smooth largescale spatial structure without significant small spatial scale motions. We show that, the existence of a region where the longitudinal velocity goes to zero linearly with distance from the wall causes the tracers to "stick" to the walls. This results in a *superdiffusive* dispersion of the tracer. We analyze the growth of the variance and show that $var(t) \sim t^{\nu}$ with $\nu = 3/2$. We model this flow using a 2D Hamiltonian system with no KAM surfaces and verify the result for the growth of the variance by numerical simulation.

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CP36

Analytic Aspects and Special Solutions of Nonlinear Partial Differential Equations

Special analytic solutions are considered for several physically important nonlinear partial differential equations. The models treated include a family of Cahn-Hilliard equations, the phi-4 equation of the family of Klein-Gordon equations, the long-wave equations, the Zakharov-Kuznetsov equation, as well as a family of reaction-diffusion equations. A combination of techniques including Lie group and direct similarity methods, traveling wave reductions, phase plane techniques, and nonlinear asymptotic analysis yields an assortment of special solutions for the equations under consideration including shock(front or heteroclinic orbit) and solitary wave(pulse or homoclinic connection) solutions. The existence of homoclinic connections and the like is verified both by the use of the stable-unstable manifold and Poincare- Bendixson Theorems, as well as by numerical simulations. Additional, often more complex, solutions are obtained by the use of truncated Painleve singularity analysis. The relevance of the derived solutions to analytic and numerical studies of the model equations with various boundary conditions is also discussed.

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CP36

Dynamics of a Nonlocal Kuramoto-Sivashinsky Equation

In this paper we study the effects of a nonlocal term on the global dynamics of the Kuramoto-Sivashinsky equation. We show that the equation possesses a "family of maximal attractors" parameterized by the mean value of the initial data. The dimension of the attractor is estimated as a function of the coefficient of the nonlocal term. Moreover, the impact of the nonlocal term on the bifurcation is discussed.

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CP36

Space Analyticity on the Attractor Generated by the Set of All Stationary Solutions for the Kuramoto-Sivashinsky Model

The numerical results obtained by P. Collet, J.-P. Eckmann, H. Epstein and J. Stubbe strongly suggest that the radius of space analyticity on the attractor for the Kuramoto-Sivashinsky equation with $L-$ periodic boundary conditions does not depend of the bifurcation parameter L . Using a lower-semicontinuity property of the analyticity radius we obtain a neighborhood (on the attractor) of the set of stationary solutions in which the conjectured phenomenon is true. Also, the description of the neighborhood does not explicitely involve L .

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CP36

Analytical Properties of PDE Jet Engine Models

We present a justification for including a viscous term in the enhanced compressor model by homogenization. We prove the existence and uniqueness of solutions of that model. Furthermore, we present some linear and nonlinear stability results and show that the stability depends on a certain Lyapunov multiplier. Finally we present a back-

stepping control scheme for the full p.d.e. model. To our knowledge, this is the first time backstepping is used on a p.d.e.

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CP36
Higher-Order Bistable Systems in One Space Dimension

We present a variational approach to the problem of analyzing multitransition solutions of a class of fourth-order evolutionary PDE's. One example is the extended Fisher-Kolomogorov equation arising in the study of convection in liquid crystals. We show the existence of stable (locally minimizing) solutions with complicated spatial patterns. This behavior is due to a loop of Shil'nikov orbits in the four-dimensional stationary ODE. Unlike other analysis of this situation, *no* conditions on these orbits, such as transversality, is required. These techniques can be extended to establish the exponentially slow motion of transition layers generally in higher-order evolution equations.

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CP36
Persistence of Invariant Manifolds for Nonlinear PDEs

We prove that under certain stability and smoothing properties of the semi-groups generated by certain PDEs, manifolds left invariant by these flows persist under C^1 perturbation. In particular, we extend well known finite-dimensional results to the setting of an infinite-dimensional Hilbert manifold with a semi-group that leaves a submanifold invariant. We apply our results to the two-dimensional Navier-Stokes equations and a perturbation consisting of a fully discrete approximation of the Navier-Stokes equation.

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CP37
On Time Optimal Control Trajectories of Biotechnological Processes

We investigate the time optimal control problem for a class of biotechnological processes described by single input nonlinear control affine systems in dimension three. Applying some recent results obtained by Sussmann, Kupka, Bonnard, and Montgomery around the Pontryagin's Maximum Principle and geometric properties of extremals such as the existence of abnormal extremals and the classification of singular extremals, we analyze time optimal trajectories and propose a classification of extremals for the considered particular systems.

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CP37
Stabilization of Uncertain Mechanical Systems Using Dynamic Feedback

Dynamic feedback refers to the specification of control forces by dynamical update laws rather than static feedback which specifies the force in terms of the instantaneous values of the state variables. This procedure requires an increase in the dimension of the phase space for the controlled system. It will be shown that such methods allow stabilization of mechanical systems to an arbitrary configuration even if the inertial and potential properties of the system are unknown.

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CP37
Stabilization of Uncertain Mechanical Systems Using Bounded Controls

This paper considers the problem of stabilizing uncertain mechanical systems in the presence of constraints on the available actuator inputs, and proposes both state feedback and output feedback controllers as solutions to this problem. Each stabilization scheme consists of a nonadaptive component for gross motion control and an adaptive component to ensure convergence to the desired configuration. The controllers are computationally simple, require virtually no information regarding the system model, and ensure that the configuration error is globally convergent. The efficacy of the proposed strategies are illustrated though both computer simulations and hardware experiments.

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CP37
Application of Symbolic Dynamics to Modeling and Control of an Internal Combustion Engine

In this presentation we illustrate the application of symbolic dynamics to the problem of cyclic combustion variations in internal combustion engines. Such variations are responsible for loss in fuel efficiency and increased pollutant emissions. Using a discrete model of the combustion dynamics, we describe our algorithm for adjusting the model parameters to "match" the observed symbolic dynamics. We also find that on-line feedback engine control might be accomplished with highly discretized measurements of cycle-resolved combustion.

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CP37
Nonlinear Regenerative Machine Tool Vibrations

Three topics are addressed. First, a regenerative machine tool vibration model is proposed in the form

$$x''(s) + 2\kappa\frac{\alpha}{v}x'(s) + \frac{\alpha^2}{v^2}x(s) =$$

$$\frac{k_s}{mv^2}\int_0^h w(\sigma)\left(x(s-\sigma-v\tau) - x(s-\sigma)\right)\mathrm{d}\sigma + \text{h.o.t.}\,.$$

Stability charts are presented for different weight functions w which describe different stress distributions on the active face of length h of the tool. Second, experimental results will be presented for thread cutting which initiate the third topic, the question of relevant non-linear effects in the model (covered by h.o.t. above), bifurcation and singular perturbation analysis, and the possible existence of chaotic and/or transient chaotic behavior.

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CP37
Dynamical Response of a Spherical Pendulum to Roll and Pitch Excitation

The operability of cranes or crane-like structures placed on ships or other floating platforms is determined by the dynamical response of the crane to the prevailing sea state. As a rudimentary model of a crane structure, we experimentally investigate the dynamical response of a spherical pendulum that is excited by a six-axis (three translational, three rotational) ship motion simulator. Due to the very light damping present (as in real cranes), the dynamics is primarily transient-dominated, and we empircally investigate transient-related effects such as low-frequency response modulation and transient length.

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CP37
On a New Route to Chaos in Railway Dynamic

A detailed investigation of a speed range with complicated dynamics of the Cooperrider truck has revealed new bifurcations and the existence of two asymmetric quasiperiodic solutions. They bifurcate supercritically as unstable solutions and stabilize in a saddle-node bifurcation. A FFT plot shows that one of the two periods has only very little power. When the speed is lowered, that period undergoes a period doubling sequence, which develops ¿ into chaos.

Hans True
The Technical University of Denmark
Carsten Nordstroem Jensen
ES-Consult
Vedbaek, Denmark

MS01
Spatio-Temporal Chaos in Rayleigh-Benard Convection

We present experimental results on spatio-temporal chaos in the convection pattern of a fluid heated from below. We show that the stationary states of perfect ordered rolls are stable to finite perturbation in the regime where spiral defect chaos (SDC) is observed. We will discuss the importance of the observed bistability for the spatio-temporal evolution of SDC.

E. Bodenschatz
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MS01
A Primary Bifurcation to Spatio-temporal Chaos

We present an experimental study of electroconvection (EC) using the nematic liquid crystal *4-ethyl-2-fluoro-4′-[2-(trans-4-pentylcyclohexyl)-ethyl] biphenyl*. The system undergoes a forward hopf bifurcation from a spatially uniform state directly to a pattern that exhibits spatio-temporal chaos. In principle, the dynamics can be quantitatively described by coupled complex Ginzburg-Landau equations that are derived from the fundamental equations of motion for EC. Such a quantitative comparison will provide useful insights into the nature of spatio-temporal chaos.

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Brown University
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MS01

Competition Between Spiral Waves and Targets in Dictyostelium Discoideum

This talk describes two studies of the spatio-temporal dynamics of chemical waves in populations of *Dictyostelium discoideum*. We study the competition between pacemakers and spirals, showing first that targets dominate at low population density, but spirals entrain autonomous pacemakers at high density. Second, we show that chemical waves can be reset by extrinsic cyclic AMP. They reappear if resetting is early in the signaling stage, but targets dominate following late resetting. This behavior correlates with the wave signal-to-noise ratio. Speculations on these observations are presented.

Raymond E. Goldstein
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MS01

Transitions from Spiral Waves to Chemical Turbulence in a Reaction-Diffusion System

We present our experimental results on transitions from regular spiral chemical waves to defect-mediated turbulence in a reaction-diffusion system with the Belousov-Zhabotinsky reaction. Three routes leading to the destruction of the spiral pattern were observed in different control parameter regimes: via Eckhaus instability or convective instability; via spiral meandering instability; and via instability induced by external forcing. The first two instabilities produce point-defects, while third instability gives line-source type defects.

Qi Ouyang
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MS02

Advection Induced by the Breaking of Vorticity Conservation via Viscous Dissipation.

Fluid transport afforded by the breaking of vorticity conservation via viscous dissipation is examined. A vorticity conserving base flow is assumed to possess a homoclinic or heteroclinic orbit. The splitting of this separatrix under a perturbation permits advection between regimes of different characteristic motion. A vorticity dissipating flow with viscous parameter ϵ and small time dependent forcing is shown to maintain an $\mathcal{O}(\epsilon)$ closeness to the vorticity conserving flow in a weak sense. A Melnikov theory is developed for such a weak perturbation, and a surprisingly simple expression derived for the leading order distance between the perturbed manifolds, which depends only on the inviscid flow. Heteroclinic orbits generically split apart with no intersection between them, while homoclinic orbits may have only higher order intersections. Viscous dissipation therefore yields a retrograde nmechanism for advection, while suppressing chaotic transport severely.

Sanjeeva Balasuriya
Department of Mathematics, University of Peradeniya, Sri Lanka

Christopher K. R. T. Jones and Bjoern Sandstede

MS02

Mathematical Problems in the Theory of Shallow Water

We consider two models of shallow water, the so-called lake and the great lake equations, which were proposed by Camassa, Holm and Levermore, and which describe the long-time motion of an inviscid, incompressible fluid contained in a shallow basin with a slowly spatially varying bottom, a free upper surface and vertical side walls, under the influence of gravity and in the limit of small characteristic velocities and very small surface amplitude.
From a mathematical point of view, the following issues arise:
- Are there weak/classical/analytic solutions?
- Are the solutions unique?
- How does bottom topography affect the solutions?
- Are the solutions to the shallow water equations in some sense "close" to solutions of the full three dimensional fluid equation? In other words, can the asymptotic expansion be mathematically justified?

The talk will briefly motivate these questions and survey the current state of the subject.

Marcel Oliver
Department of Mathematics,
University of California at Irvine

MS02

Inverse Scattering Analysis of Internal Waves in the Andaman Sea

Internal wave data taken in the Andaman Sea in 1976 are revisitedin light of recent advances for the analysis of data using the inverse scattering transform. As is well known [Osborne and Burch, 1980] these data exhibit solitons with amplitudes up to 110 m and particle velocities up to 2.5 m/s. In the present work I use the periodic inverse scattering transform in the theta function representation to analyze the data. I use both the oscillatory basis (for which the nonlinear modes are cnoidal waves) and the soliton basis. Explicit computation of the nonlinear interactions among the components is also made. A number of theorems about theta functions are invoked to isolate the solitons from the radiation and to nonlinearly filter the data in a number of novel new ways. I also search for triad interactions among the components of the inverse scattering transform. The results suggest that the periodic inverse scattering transform will serve a new and fundamental role in the understanding of the nonlinear dynamics of the internal wave field in a wide variety of locations around the world.

A. R. Osborne
University of Torino, Turin, Italy

MS02

Dynamical Systems Theory and Dynamical Oceanography

It is well known that the discovery by Lorenz of non-periodic deterministic motion in dissipative dynamical systems occurred within the discipline of dynamical meteorology, the study of the large-scale dynamics and thermodynamics of the atmosphere. Despite many similarities

between the underlying dynamics of oceanic and atmospheric motions, which have resulted in the development of the general field of 'geophysical fluid dynamics,' the phenomenon of chaos in low-order systems has received relatively less attention in dynamical oceanography, the study of the large-scale dynamics and thermodynamics of the ocean. Some early oceanographic applications of these ideas derived from simple models of forced flow over topography, in which asymptotic analysis led directly to low-order systems that exhibited chaotic behavior. Recently, efforts have been made to apply the techniques of dynamical systems theory to the problem of large-scale fluid parcel dispersion in the ocean. This approach appears most suited for the study of coherent features and strongly inhomogeneous flows, and in these cases has yielded new insights into the kinematics of dispersion. Many questions concerning the relation of this picture to the dynamics of critical layers, instabilities, and potential vorticity homogenization remain unanswered.

Roger M. Samelson
Woods Hole Oceanographic Institution,
Woods Hole, MA

MS03

Augmentation of Sensory Nerve Action Potentials during Muscle Contraction

We previously reported that the median sensory nerve action potentials (SNAP's) increased in amplitude during ipsilateral abductor pollicis brevis (APB) contraction. The objectives of the present project were to study the timing and origin of this phenomenon and eliminate the possibility of local artifact. Ten normal subjects were recruited. The baseline was established using 10 threshold stimuli which were delivered to the median nerve at the wrist at 0.2 Hz. Using the same stimulus strength, the SNAP was recorded while the tibialis anterior (TA) was contracted at 25signal averaged. Results showed an increase in ipsilateral SNAP amplitude between baseline to maximal contraction of 6 +/- 2 uV (SE, p= .004) and contralateral amplitude of 8 +/- 2 uV (SE, p = .01). Statistical analysis was performed with ANOVA for repeated measures and paired t-test. The effect peaked between 0 to 10 minutes after contraction and lasted from 1.5 to over 20 minutes after muscle relaxation. In conclusion, SNAP's appear to be enhanced during and after muscle contraction. Theories concerning underlying causes for this event including central augmentation and muscle tension noise enhanced signal transmission are discussed.

Faye Y. Chiou-Tan
Kevin N. Magee, Stephen Tuel, Lawrence Robinson,
Thomas Krouskop, Maureen R. Nelson, and Frank Moss
Department of Physical Medicine and Rehabilitation
College of Medicine, Huston TX

MS03

Noise-Enhanced Sensory Function

Noise can enhance the detection and transmission of weak signals in certain nonlinear systems, via a mechanism known as stochastic resonance (SR). Here we describe studies in which SR-type behavior is demonstrated in: (i) model neurons, (ii) rat cutaneous sensory neurons, and (iii) the human touch-sensation system. This work suggests that it may be possible to develop a noise-based technique for lowering sensory detection thresholds in humans. The bioengineering and clinical ramifications of such a development will be discussed.

James J. Collins
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MS03

Stochastic Resonance in Human Muscle Spindles-a potential mechanism for fusimotor gain control

Stochastic resonance is a phenomenon in both physical and biological systems where a particular level of random noise improves signal detection. In systems where detection is near threshold, a random noise input can improve sensitivity to small amplitude signals by boosting the receptors above threshold. One biological system that could potentially benefit from stochastic resonance is the proprioceptive system, which provides us with the sense of body position and movement. Stochastic resonance could enhance proprioception when movements are novel or must be made extremely precisely. We demonstrate stochastic resonance in human muscle spindle receptors-an important source of proprioceptive information for movement coordination. We hypothesize that stochastic resonance is the mechanism with which the fusimotor system increases the gain of muscle spindles during novel and precise movements.

Paul J. Cordo
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Sabine M. P. Verschueren
Catholic University of Leuven
Heverlee, Belgium
J. Timothy Inglis
University of British Columbia
Vancouver, B.C. Canada
Frank Moss
University of Missouri at St. Louis
St. Louis, MO
Daniel M. Merfeld
R.S. Dow Neurological Sciences Institute
Portland, OR
James J. Collins
Boston University
Boston, MA

MS03

Noise, Hair Cells, & the Leopard Frog

Auditory synapses are capable of transmitting timing and intensity information with unparalleled fidelity. Yet the performance of certain auditory functions is best for near-threshold stimuli, just where external noise would seem to be most destructive. Curiously, two important steps in the process of sensory transduction in hair cells – the mechanoelectrical transduction resulting from deflection of the hair bundle and the gating of voltage-dependent calcium ion channels – are described by dynamical models known to exhibit stochastic resonance.

Kurt Wiesenfeld,
Peter Jung,
School of Physics, Georgia Institute of Technology, Atlanta, GA 30332

Fernan Jaramillo
Department of Physiology, Emory University, Atlanta, GA 30322

MS05
Encoding Information in Chemical Chaos

We describe encoding and decoding symbol sequences containing information into chaotic oscillations of the Belousov-Zhabotinsky reaction. Encoding is based on controlling chaotic oscillations by applying small parameter perturbations and on learning corresponding symbol dynamics produced by the free-running chaotic system. Use of small parameter perturbations requires that we respect the grammar of the symbolic dynamics. We present a general method for learning the grammar in terms of transitions between bins defined by the generating partition.

Erik M. Bollt
United States Military Academi, West Point, NY

MS05
Experimental Control of Chaos for Communication

The experiments done to demonstrate the use of chaos to transmit information will be described. The symbolic dynamics of a chaotic electrical oscillator is controlled to carry a prescribed message by use of extremely small perturbating current pulses. A movie will be shown demonstrating the whole experimental encoding sequence in real time.

Scott Hayes
Army Research Laboratory, Adelphi, MD

MS05
Higher Dimensional Symbolic Encoding

The use of higher dimensional dynamical systems in communication with chaos brings a few potentially technologically relevant advantages. In particular, it allows for more practical high-speed symbolic control techniques that could be used at higher bit rates than an implementation in a low dimensional dynamical system. In this talk a symbolic encoding technique for a chaotic signal to be used in communication will be discussed.

Ying-Chen Lai
University of Kansas, Lawrence, KS

MS05
Noise Filtering in Communication with Chaos

I will present a method based on fundamental properties of chaotic dynamics for filtering in-band noise of an incoming signal generated by a chaotic oscillator. Initially the 2x mod 1 map is used to illustrate the procedure and then the method is applied to recover the message encoded in a realistic chaotic signal, after the transmitted signal has been contaminated with noise.

Epaminondas Rosa, Jr.
University of Maryland, College Park, MD

MS06
Predicting Spiral Chaos in Rayleigh-Benard Convection: a Phase Dynamics Approach to the Onset and Properties of Spatio-Temporal Chaos

The theoretical prediction of the onset of spatiotemporal chaos and the properties of the resulting dynamic state from first principles is a daunting task. I describe a first attempt to do this for the spiral spatiotemporal chaos in Rayleigh-Bénard convection using a systematic reduction of the equations for the motion of the local spatial structure known as "phase dynamics". The importance of invasive defects in the chaotic dynamics is proposed. Numerical simulations of the spiral state and the role of the vertical fluid vorticity in the dynamics will also be discussed.

M. C. Cross
California Institute of Technology, Pasadena, CA

MS06
Using Finite-Time Lyapunov Dimensions to Measure the Dynamical Complexity of Topological Defects

We have defined a finite-time Lyapunov dimension D^T based on the evolution of Lyapunov vectors over short time intervals of length T. For the complex Ginzburg-Landau equation in two spatial dimensions, D^T is, on average, linearly related to the mean number of defects in the system during the same time interval. The average dimension per defect is about 2 over a wide range of parameter values. In an effort to understand whether this result extends to other defect-dominated chaotic systems, we extend this work to other states such as spiral defect chaos in a generalized Swift-Hohenberg equation

D. Egolf
Cornell Theory Center, Cornell, NY

MS06
Phase Diffusion in Localized Spatio-Temporal Amplitude Chaos of Parametrically Excited Waves

In simulations of coupled Ginzburg-Landau equations for parametrically excited waves we find *fluctuating* defects in the form of double phase slips, which eliminate and reinsert a wavelength in the periodic pattern. In large systems they lead to spatio-temporal amplitude chaos. Despite the break-down of the usual phase equation during each phase slip the large-scale behavior can be described by an *effective* phase equation. We determine the phase-diffusion coefficient explicitly. Its wavenumber dependence leads to stable states consisting of alternating domains of regular and spatio-temporally chaotic dynamics. For this system the phase equation plays a role similar to that of the KPZ-equation for the Kuramoto-Sivashinsky equation. Formally, it can be considered to arise from a spatio-temporal homogenization of the chaotic state.

Glen D. Granzow
Northwestern University, Evanston, IL

Hermann Riecke
Northwestern University, Evanston, IL

MS06
Suppressing Spatiotemporal Chaos Using Time-Delay Feedback

We introduce a spatially local feedback mechanism for stabilizing periodic orbits embedded in spatially extended chaotic attractors. Our method, which is based on a comparison between present and past states of the system, does not require external generation of a reference state and can suppress both absolute and convective instabilities. We also show that the inclusion of a spatial filter in the feedback loop results in the stabilization of traveling waves in a

model of a transversely extended semiconductor laser. The scheme we study can be implemented in a straightforward manner to obtain real-time control of optical systems. Our results are derived both from exact linear stability analysis and from numerical simulation of model partial differential equations.

Michael E. Bleich
Duke University, Durham, NC

Joshua E. S. Socolar,
Duke University, Durham, NC

David Hochheiser
University of Arizona, Tucson, AZ

Jerome V. Moloney
University of Arizona, Tucson, AZ

MS07
A Leading-Order Singular Hamiltonian Perturbation Method in Fluid Dynamics

We consider the question of constructing a singular Hamiltonian perturbation method for systems with generalized Poisson brackets. In partial answer to this question we have found a leading-order singular Hamiltonian perturbation method by combining asymptotic perturbation expansions, based on a slave relation between the fast variables and the slow master variables, with preservation of the Hamiltonian formulation. In our method the distinction between fast and slow variables stems from the assumed time scale separation of the linear (wave) problem. These leading-order results have been exemplified by a systematic derivation of the Hamiltonian formulation for the incompressible, homogeneous fluid equations via a Mach-number expansion and for the barotropic quasi-geostrophic fluid equations via a Rossby-number expansion. Although these and many other leading-order Hamiltonian formulations of various dynamical systems, in particular approximate fluid equations, have been recorded previously, our method provides a unified Hamiltonian view on a hierarchy of approximations made in (geophysical) fluid dynamics. The formulation of a tractable higher-order singular Hamiltonian perturbation method is still unresolved. However, we have illuminated the link between Dirac's theory of constrained Hamiltonian systems and formal manipulation of the slave relation within a cosymplectic formulation of the equations of motion.

Onno Bokhove
Woods Hole Oceanographic Institution
Woods Hole, MA

MS07
On Hamiltonian Balanced Models of Atmosphere-Ocean Eddy Dynamics

The general mathematical structure of hamiltonian balanced models of vortical atmosphere–ocean dynamics is clarified, at arbitrary accuracy, along with its relation to the concepts of slow manifold and potential-vorticity (PV) inversion. Accuracy means closeness to an exact dynamics, meaning a primitive or Euler-equation hamiltonian dynamics, regarded as the exact 'parent' of the balanced model. Arbitrary means limited not by any particular expansion method or approximate formula, or fast–slow scaling assumption, but only by the irreducible, residual inaccuracy or imbalance associated with the spontaneous adjustment emission, of inertia-gravity waves by unsteady vortical motions. The clarification shows (a) which features of hamiltonian balanced models, like Hoskins' semigeostrophic theory, are special and which are general, and how such models can be generalized to arbitrary accuracy without losing hamiltonian structure, (b) how such generalizations can be constructed, at least formally, by inserting into the hamiltonian framework any of the highly accurate balance conditions used in recent studies of accurate PV inversion, and (c) how, in a certain class of models, canonical coordinates, analogous to Hoskins' geostrophic-momentum coordinates, can be found. A quaternionic structure has been identified within the class of such models.

Ian Roulstone
UK Meteorological Office,
Berkshire, United Kingdom

MS07
Statistical-Dynamical Methods in Atmospheric Prediction

Atmospheric prediction has historically been an applied science which has provided early examples of mathematically interesting phenomena such as low order chaotic dynamics and sensitive dependence on initial conditions. Over the past several years, operational forecasting centers have initiated research in two major areas which, by the nature of the posed forecast problems, require the development of methodologies for dealing with the fact that the atmosphere is a system with a very large number of degrees of freedom and which exhibits sensitive dependence on both initial conditions and forcing. These two areas are four-dimensional data assimilation, for the purpose of initial state estimation, and coarse grained probabilistic predictions at the limits of deterministic predictability, for extended range outlooks. Both problems will be reviewed and the current state of the art techniques will be discussed. The limitations of the currently used methods, which are derived from linear theory, will be examined and the necessity of nonlinear extension will be suggested. The position taken will be that in order to reach a level of utility commensurate with computational expense probabilistic predictions in the short range (for data assimilation purposes) or the extended range (for climatic anomalypredictions) must be capable of giving probabilistic information for the situation where a probability density forecast becomes multi-modal. A prototypical, simplest example of such a situation is the planetary-wave regime transition which will be examined in detail.

Joe Tribbia
NCAR, Boulder, CO

MS07
Averaging and Reduced Dynamics in Simple Atmospheric Models

We use hamiltonian averaging theory (equivalent to transformation to normal forms) to study reduced, or balance, dynamics in a series of simple hamiltonian models of atmospheric circulations. The existence of higher-order adiabatic invariants in some of these models can be used to construct reduced models which are exponentially accurate in the sense that the unbalanced part of the dynamics grows in exponentially long timescales.

Djoko Wirosoetisno
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Theodore G. Shepherd
University of Toronto
Toronto, Canada

Daniel T. Kaplan
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Macalester College, St. Paul, Minnesota

MS08
Markov Chain Monte Carlo Methods in Nonlinear Signal Processing

Dealing with noisy data leads to problems of estimating both the system dynamics and the true states in the reconstrcuted space. We demonstrate that Markov Chain Monte Carlo methods provide a powerful approach to solving such problems, particularly when the noise levels are high.

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MS08
Modeling Noisy Chaotic Data

A generalization of the minimization of the one–step–prediction error is presented, which allows one to reconstruct the dynamics underlying chaotic data contaminated by large amplitude measurement noise, in an unbiased way. Moreover, this new cost function offers a new approach to modeling in the case of noise interacting with the deterministic dynamics.

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MS08
Embedding in the Presence of Dynamical Noise

We present a simple new result in the spirit of Takens's embedding theorem, but requiring multivariate signals. Our result extends the domain of geometric time series analysis to some genuinely stochastic systems, including such natural examples as

$$x_{j+1} = \phi(x_j) + \eta_j,$$

where ϕ is some fixed map and the η_j are small, i.i.d. random displacements.

M. Muldoon, J.P. Huke & D.S. Broomhead
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MS08
Processing of Noisy Nonlinear Signals: The Fetal ECG

Electrocardiographic (ECG) recordings are characterized by a combination of nonlinear structure on time scales shorter than one cardiac cycle and a stochastic component in the triggering of new cycles. We show that nevertheless, phase space embedding yields a useful parametrization and forms an appropriate framework for the processing of such signals. As an example we apply phase space projections to extract the fetal component from noninvasive maternal ECG recordings.

Thomas Schreiber and Marcus Richter
Physics Department, University of Wuppertal, Wuppertal, Germany

MS09
On The Jump Phenomenon in Coupled Oscillators

For the study of the jump phenomenon in a system with two degrees of freedom two oscillators, coupled by polynomials of the seventh degree are considered. For this system a normal form is presented in case of non resonance. This normal form is a quartic Kolmogorov system in the plane. Some results of the analysis of this system are presented. Also an interpretation of these results for a special application is given.

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MS09
New Developments in Forced and Coupled Relaxation Oscillations Amersed-Boundary Method

Relaxation oscillations form an important class of dynamical systems in electric circuits, biology and other fields. Forced van der Pol relaxation oscillator provided one of the first examples of deterministic chaos, through the work of Cartwright, Littlewood and Levinson. The physical significance of such chaos is limited by the fact that it unobservable directly: the measure of the corresponding hyperbolic invariant set is zero. We will present a class of closely related relaxation oscillators which do exibit a physically observable chaos, with the positive measure of chaotic orbits.

Mark Levi
Rensselaer Polytechnic Institute, Troy, NY 12180

MS09
Transition Curves in the Quasiperiodic Mathieu Equation

In this work we investigate the following quasiperiodic Mathieu equation:

$$\ddot{x} + (\delta + \epsilon \cos t + \epsilon \cos \omega t)\, x = 0$$

We use numerical integration and Lyapunov exponents to determine transition curves bounding regions of stability in the $\delta - \omega$ plane for fixed ϵ. In addition, we obtain approximate analytic expressions for these transition curves using two distinct methods: regular perturbations and harmonic balance. Comparison of the results of these methods with those of numerical integration shows that the perturbation method fails to converge in the neighborhood of resonant values of ω. The results obtained by harmonic balance do

not display this undesirable feature.

Randolf S.Zounes
Cornell University, Ithaca, NY

Richard H.Rand
Cornell University, Ithaca, NY

MS09
Symmetric and Asymmetric Dynamics of Linearly Coupled van der Pol Oscillators

We present the results of analytical and numerical studies of the dynamics of a pair of van der Pol oscillators with linear diffusive coupling. A critical variational equation, whose stability corresponds to that of the symmetric (in-phase and out-of-phase) modes, is derived and transformed to a Hill's equation to identify a sequence of resonant instabilities. Perturbation methods are used to determine the extent of the resonances and a ruled surface, corresponding to zero mean damping, which completes the stability transition set. Pade approximants are used to obtain extended-range approximations of the intersection curves between the resonances and the mean damping surface. Numerical simulations are presented to demonstrate the existence of asymmetric and non-periodic trajectories, and to illustrate the effect of detuning.

Duane W. Storti
University of Washington, Seattle, WA

Per G. Reinhall
University of Washington
Seattle, WA

David M. Sliger
University of Washington
Seattle, WA

MS10
Use of Mathematical Methods for Protocol Design in Cancer

Analysis of populations undergoing periodic loss process, which is effective only during part of the life-cycle, pinpoints the phenomenon of resonance in population survival. Resonance arises when the period of the imposed loss process coincides with the inherent reproductive periodicity of the population. Such a coincidence results in a preferential enhancement of population growth. This general phenomenon has been verified experimentally and has been employed for devising a method, (*the Z-Method*) for minimizing the cytotoxic side-effects in cancer chemotherapy.

Zvia Agur
Tel-Aviv University, Israel

MS10
Clinical and Mathematical Aspects of Resetting and Entraining Reentrant Tachycardia

Reentrant tachycardia is a serious medical problem in which cardiac activity travels in a circuitous pathway. This problem is sometimes diagnosed and treated by the direct electrical stimulation of the heart by catheters inserted directly into the heart. The procedure involves applying stimuli in various protocols and sequences. To understand these procedures, it is necessary to consider the resetting of limit cycle oscillations in partial differential equations. The bridge between the clinical and theoretical aspects will be emphasized.

Leon Glass
Department of Physiology
McGill University, Montreal, Canada

MS10
Spectral Properties of the Tubuloglomerular Feedback System

The tubuloglomerular feedback system, which regulates blood plasma processing by the kidney, may exhibit oscillations in key variables. Physiologists have used spectral analysis to interpret these oscillations. We have formulated a mathematical model for this system and investigated its spectral properties. The analysis appears to explain salient features of experimental power spectra, and the analysis demonstrates that great care is required in the calculation of spectra from models and in the interpretation of experiments.

H. E. Layton
Duke University, Durham, NC

E. B. Pitman
State University of New York, Buffalo, NY

L. C. Moore
State University of New York, Stony Brook, NY

MS10
Modeling the Pupil Light Reflex with Delay Differential Equations

The pupil light reflex (PLR) is the paradigm of a human neural feedback control mechanism. This reflex is time delayed and the open-loop transfer function is 3rd-order. Considerations of the iris muscle plant, its neural input and the feedback lead to a model for the PLR expressed in terms of a 3rd-order delay differential equation. The properties of this equation are discussed with respect to two important pupil phenomena: the pupil size effect and "fatigue" waves.

John Milton
The University of Chicago
Chicago, USA

Jacques Bélair
Université de Montréal
Montreal, Canada

MS11
Scaling Relations in Chemical Spirals: Selection and Dispersion

We present an experimental survey of spiral waves in the Belousov-Zhabotinsky reaction using an open spatial reactor. The selected pitch p_s and period T_s are measured for various chemical concentrations; they follow the relation $p_s \sim T_s^{1/2}$. Taking advantage of the system's sensitivity to light, we impose a longer period on the spiral and thereby determine the dispersion relation at different concentrations, which collapse onto a single dimensionless curve when appropriately rescaled. We derive a functional form for the curve from a model of the underlying chem-

istry.

Andrew Belmonte[1], [1], Jean-Marc Flesselles[1], [2], Vilmos Gáspár[2], and Qi Ouyang[1]. [3] [1] Institut Non-Linéaire de Nice, Valbonne, France; [2] Kossuth Lajos University, Debrecen, Hungary

MS11
The Dynamics of Scroll Wave Filaments in the Complex Ginzburg-Landau Equation

We present an analytical treatment for scroll waves evolving under the Complex Ginzburg-Landau Equation in the limit of small filament curvature and phase twist. Expressions for the collapse rate, drift rate, and frequency shift are found. Our treatment shows the existence of wavenumber shifts in the plane of the spirals; a feature not included in previous theories of scroll waves. We verify our results numerically for circular untwisted rings and for twisted and untwisted sinusoidal filaments. We also display numerical evidence for reconnection of adjacent filaments and of the instability of straight filaments with strong twist.

Michael Gabbay
University of Maryland
College Park, MD

Edward Ott
University of Maryland
College Park, MD

Parvez Guzdar
University of Maryland
College Park, MD

MS11
Control of Spiral Territories in Dictyostelium

The aggregation stage of the life cycle of **Dictyostelium discoideum** is governed by the chemotactic response of individual amoebae to excitable waves of cyclic AMP (cAMP). Quite often, these waves take the form of large spirals and lead to the formation of aggregation territories with roughly 10^5 cells each. We model this process via a recently-introduced hybrid automata-continuum scheme and use computer simulation to unravel the role of specific components of this complex developmental process. Our results indicate an essential role for positive feedback between the cAMP signaling and the expression of the genes encoding the signal transduction and response machinery.

Herbert Levine
Univ. of California, San Diego
La Jola, CA 92093

MS11
Optical Tomography of Chemical Waves in Three Dimensions

Numerically solving the partial differential equations of excitability revealed topologically distinct persistent solutions like linked and knotted vortex rings (Science 371, 233 [1994]; Physica D 84, 126 [1995]). No attempts to determine whether these also occur in nature have succeeded, for want of a way to capture moving transparent color patterns 3-dimensionally. My 1992 plan for such a device is now a working reality: (Chaos 6(4) [1996]); http://cochise.biosci.arizona.edu/ art

Arthur T. Winfree
326 BSW, University of Arizona, Tucson, AZ

MS12
A Unified Approach to Interacting Particle Systems and Stochastic PDE Using Measure-Valued Processes

We present an introduction to the application of measure-valued processes to model interacting particle systems and lattice systems which arise in the physical and biological sciences, their approximation by stochastic partial differential equations of parabolic type and some examples of spatial clumping phenomena which can be understood by using these methods.

Donald Dawson
The Fields Institute, Toronto, Canada

MS12
Effect of Noise on Bifurcations in Spatially Extended Systems

The effect of space-time noise in model partial differential equations with a symmetry-breaking transition is studied numerically and analytically. Additive noise is important when the critical parameter is a function of time; the delay of the transition is a function of the log of the noise magnitude. Multiplicative noise makes the statistics non-Gaussian; its effect is proportional to its magnitude.
keywords: stochastic PDEs, multiplicative noise, critical phenomena, symmetry-breaking, pattern formation.

Grant Lythe
Center for Nonlinear Studies
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MS12
Width of Wavefronts for Random Travelling Waves

We consider the super-critical super-Brownian motion in 2 or more dimensions. Under certain initial conditions, this process has a random travelling wave. We give a definition for the width of the wave, and show that the width is stochastically bounded. Roughly speaking, we examine the process along a line which is perpendicular to the wavefront, and measure the wavefront as it intersects this line. We do not expect the entire wavefront to have finite width. Although our results are limited to this model, we believe that the same phenomenon holds for a large class of random growth models. To prove our result, we exploit the connection between the super-critical super-Brownian motion and the Kolmogorov-Petrovskii-Piscuinov equation. Using the Feynman-Kac formula, we study travelling waves for the Kolmogorov-Petrovskii-Piscuinov equation. Using this information, we then deduce our result for the super-critical super-Brownian motion.

Carl Mueller
Department of Mathematics
University of Rochester
Rochester, NY 14627
Roger Tribe

Mathematics Institute
University of Warwick
Coventry CV4 7AL
England

MS12
Front Propagation in Noisy Burgers Type Equations

It is well-known that traveling front solutions to scalar conservation laws with convex flux are stable up to a phase shift for large times if the initial perturbations have enough spatial decay. When the initial perturbation is a stationary random process or the convex flux is spatially random, we show for Burgers type equations that front structures persist and front location obeys the law – mean velocity times t plus Gaussian noise.

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MS13
Diurnal Vertical Migration, A Mechanism for Patchiness in Shear Flows

Diurnal vertical migration is a common behavioural characteristic of (herbivorous) zooplankton (Z), contrasting with the photosynthesising phytoplankton (P), which behave much more like passive suspensions in the ambient fluid flow. When shear is present, this different behaviour implies different advective effects for P and Z. We use simple models to demonstrate that one consequenceis the development of strong patchiness in the populations of P and Z on scales dictated by shear strength and biological parameters.

John Brindley
University of Leeds, Leeds, UK

Louise Matthews
University of Leeds, Leeds, UK

MS13
Vertical Migration in Phytoplankton-Zooplankton Interactions

Based on empirical evidence documenting the importance of size classification in phytoplankton-zooplankton interactions, various models have been proposed which generalise the aggregate NPZ model to include such classifications. However, different sizes and species of zooplankton differ markedly in behaviours such as vertical migration. In this talk I present a simple 2-class food chain model which incorporates vertical migration of the larger zooplankton class, and study the effects this migration has on the dynamics of the populations.

Kathleen Crowe
University of California, USA

MS13
Spatial Structure in Oceanic Plankton Populations

The coupling of nonlinear interactions in aquatic communities to periodic chemical and physical forcing can cause numerous spatial and spatio-temporal patterns. A simple model of phytoplankton-zooplankton dynamics in space and time is presented as an example. The temporal and spatial patterns in natural nutrient-plankton-fish systems are interpreted as transient and stationary nonequilibrium solutions of dynamical nonlinear interaction-diffusion-advection models. Nutrients and planktivorous fish are treated as control parameters, varying in space and time. For constant parameters, local properties as multiple stability, oscillations and excitability are found. Periodic forcing through temperature, light or nutrient variability as well as periodic fish invasions can drive the system from regular predator-prey limit-cycle oscillations to deterministic chaos via quasi-periodic torus oscillations and their destruction. It is shown, that the external forcing does not necessarily lead to unpredictable chaotic dynamics but can even stabilize the system's behaviour. Having regard also to diffusion and advection, the emergence of standing and travelling population patches is obtained. These waves appear after diffusion-induced (Turing) or diffusion-advection-induced (DIFII) instability of a spatially uniform population distribution, considering phytoplankton as the activating and zooplankton as the inhibiting species. Under relative physical uniformity, the latter mechanisms are suggested as possible ways to generate the patchy plankton patterns, observed in natural systems. Compared to the Turing instability, the differential-flow-induced instability (DIFII) is a much more general mechanism of spatio-temporal pattern formation because it does not depend on the condition of considerably different diffusion coefficients but only on the condition of different species velocities, regardless of which one is faster.

Professor Horst Malchow
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MS13
Chaotic Advection and Plankton Patchiness

We discuss plankton distributions and interactions arising in velocity fields driven by wind or thermohaline effects (e.g. Langmuir circulation, thermohaline convection). We show that the Unsteady velocity field affects the distribution of plankton by chaotic advection, provides a mechanism of replenishment of Stommel Retention Zones and an explanation for the observed disappearance of patchiness of plankton population under high-wind conditions. We discuss the effects of different plankton population dynamics and convective velocity fields on asymptotic spatio-temporal states.

Igor Mezic
Dept. of Mech. & Environ. Eng.
University of California,USA

MS14
A Finite Element Method for the Frobenius-Perron Operator Equation

We present a general class of finite element methods to solve numerically the absolutely continuous invariant mea-

sure problem associated with a multi-dimensional nonsingular transformation. This class includes the method of Markov finite approximations and the projection method, in particular the original Ulam method. The convergence of the method will be proved for the class of piecewise expanding maps with the help of the bounded variation technique. The convergence rate analysis will also be given.

Jiu Ding
The University of Southern Mississippi
Hattiesburg, MS

Aihui Zhou
Institute of Systems Science
Academia Sinica
Beijing 1000080, China

MS14

Computing Physical Measures of Mixing Multidimensional Systems with an Application to Lyapunov Exponents

We present new results on the rigorous computation of physical invariant measures of higher dimensional mixing transformations, including a new method of proof of Ulam's conjecture. The exponential mixing property guarantees that the system is sufficiently insensitive to errors in the approximation algorithm. Our method has the advantages of having very relaxed conditions on its numerical implementation, being applicable to higher dimensional systems, and potentially applicable to a wide class of maps. The numerical approximation of the physical measure is used directly to estimate the Lyapunov exponents of the system. The exponents are calculated as an integral of a special "stretching function" over phase space (a space average), rather than by following a single long orbit (a time average).

Gary Froyland
The University of Western Australia
Perth, AUSTRALIA

MS14

Approximating Attractors and Chain Transitive Invariant Sets with Ulam's Method

In a departure from its customary application Ulam's method is used for maps where the physical measure is possibly singular with respect to Lebesgue measure. The method can be used to approximate a large class of Lyapounov stable attractors and more general sets associated with the long time dynamics of the map.

Fern Hunt
National Institute of Standards and Technology
Gaithersburg, Maryland

MS14

Markov Finite Approximation of Frobenius-Perron Operators and Invariant Measures for Set-Valued Dynamical Systems

We view a method proposed by S. Ulam as a discrete stochastic approximation of a dynamical system by a random perturbation modelled by a Markov chain induced by a partition of the state space. This leads to an alternative view of a set-valued amp as an aggregate of random perturbations from which notions of Frobenius-Perron operator and invariant measure for set-valued maps follow. In this light Ulam's method is seen to have a natural extension to the set-valued case-giving discrete stochastic approximations of Markov processes by Markov chains.

Walter Miller
Howard University
Washington D.C.

MS14

Cone conditions and error bounds for Ulam's method

Fundamental to error bounds for Ulam's Markov approximation scheme for approximating invariant measures are estimates of the rate of mixing for the dynamical system. Liverani [4] has recently shown how certain *cones* of functions can be used to good mixing estimates. Using expanding circle maps as an example, I will show how the continuous structures can be "discretized" to get explicit quantitative bounds for the approximation error in Ulam's method[5]. Generalizations will be mentioned briefly.

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MS15

Particle Motion in Capillary Surface Waves

The motion of drifters near the sea surface has been a crucial element in probing oceanic turbulence. In the geophysical dynamical regime, the drifter motion possesses significant persistence, showing that the motion is far from Brownian. A similar persistence is observed in laboratory experiments on capillary surface waves. We obtain results for the self-diffusivity as well as for the relative diffusivity, and compare our measurements with results obtained from turbulence theories and with observations from geophysical turbulence.

Preben Alstrøm,
Mogens T. Levinsen,
and Elsebeth Schröder
Niels Bohr Institute,
Copenhagen, Denmark

MS15

Motion of Floating Particles on a Turbulently Driven Fluid

We have studied the motion of small particles floating on the surface of a turbulent fluid and in addition, the turbulence in the underlying fluid that drives the surface particle motion. The experiment is aimed at illuminating the connection between the two. Attention was focused on measuring the R-dependence of the instantaneous root mean square velocity difference $\sigma = \sqrt{< \delta v(R)^2 >}$. In one experiment R is the separation of the surface particles; in the other, R is the separation of seed particles in the bulk fluid. The results of the study will be compared with with theoretical expectations and with analogous high Reynolds

[4] C Liverani. Decay of Correlations. *Annals of Mathematics* **142** (1995)

[5] Joint work worth M S Keane and L–S Young.

number experiments carried out in the ocean.

Walter I. Goldburg and Cecil Cheung
University of Pittsburgh
Pittsburgh, PA

MS15
Drifter Trajectories in Geophysical Flows

Some of the properties of Lagrangian trajectories in large-scale geophysical flows are discussed. Velocity statistics and single-particle dispersion are considered in detail, and the issue of relating Lagrangian and Eulerian measurements is adressed. In particular, I review some recent results on the behavior of freely-drifting subsurface buoys in the North Atlantic and compare them with the analogous results obtained for simple barotropic models such as two-dimensional turbulence and point vortices.

Antonello Provenzale
Istituto di Cosmogeofisica, Corso Fiume 4, I-10133 Torino, Italy

MS16
Long-Range Rotating Order in Extensively-Chaotic Systems

After a brief presentation of non-trivial collective behavior in extensively-chaotic systems, or, in more traditional terms, long-range order arising from spontaneous symmetry-breaking in large, chaotic, dynamical systems, I will focus on the particular case of long-range *rotating* order (LRRO), where a *continuous* global "phase" variable can describe the collective motion. I will show how "noisy synchronization" of chaotic oscillators is but a particular case of LRRO. Universal features, the connections to the Kardar–Parisi–Zhang and the complex Ginzburg–Landau equations will be discussed in light of recent numerical results on various systems.

Hugues Chate
Centre d'Etudes de Saclay, France

MS16
Spiral Waves in Chaotic Systems

Spiral waves can exist in systems whose local dynamics is chaotic or supports other types of complicated periodic behavior. The spatio-temporal structure of such systems is considerably more complex than that of simple period-1 oscillatory media. This structure has been studied in systems where a chaotic attractor arises from a period-doubling cascade or intermittency, as well as in systems displaying other types of complex periodic behavior. In the case of period doubling, as one moves from the core of the spiral wave, the local dynamics takes the form of perturbed, period-doubled orbits whose character varies with spatial location. Topological featues that underlie the organization of the medium will be discussed. Different scenarios for the spatio-temporal organization will be described for chaotic and complex-periodic dynamics that arises by other mechanisms.

Raymond Kapral
University of Toronto, Canada

MS16
Phase Synchronization of Chaotic Systems

Cooperative behaviour of chaotic dynamical systems and in particular synchronization phenomena have received much attention recently. Generally, synchronization can be treated as an appearance of some relations between functionals of two processes due to interaction. The classical case of periodic oscillators was already described by Huygens in 1673. We have recently found the new effect of phase synchronization of coupled chaotic systems. To characterize this phenomenon, we use the analytic signal approach based on the Hilbert transform. In the synchronized regime the phases are locked, whereas the amplitudes vary chaotically and are practically uncorrelated. A relation between the phase synchronization and the properties of the Lyapunov spectrum is studied. This effect has been found for different kinds of models, e.g. coupled Roessler or Lorenz attractors, periodically forced chaotic systems, and large ensembles of non-identical chaotic oscillators.

Jurgen Kurths University of Potsdam, Germany

MS16
Synchronization Transitions in Coupled Chaotic Oscillators: From Phase to Compete Synchronization

Complete, generalized and phase synchronization (CS, GS, and PS) of chaotic oscillators have been described in the literature. The relation between these different types of synchronization and the scenarios of transitions to or between them have not been addressed yet. We study synchronization of symmetrically coupled non–identical self–sustained oscillators. We demonstrate that with the increase of coupling first the transition from non–synchronous state to PS occurs; it means entrainment of phases of chaotic oscillators, whereas their amplitudes remain chaotic and non–correlated. For larger couplings a new regime which we call lag synchronization (LS) is observed. LS appears as coincidence of *shifted in time* states of two systems, $\mathbf{x}_1(t+\tau_0) = \mathbf{x}_2(t)$. This means that the relation appears not only between the phases, but also between the amplitudes. Finally, with further increase of coupling, the time shift $\tau_0 \rightarrow 0$ and this regime tends to CS. The transitions in the type of synchronization can be related to the transitions in the Lyapunov spectrum.

M. Rosenblum
Max–Plank–Arbeitsgruppe "Nichtlineare Dynamik"
an der Universität Potsdam, Potsdam, Germany;
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Russian Acad. Sci., Moscow, Russia

MS17
Synchronous and Asynchronous States in a Network of Spiking Neurons

We study the dynamics in a fully connected network of spiking neurons. As a neuron model, we use the spike response model, a generalized version of the integrate-and-fire model. The stability of asynchronous firing and of collective network oscillations is analyzed. The result can be discussed in terms of biological paramters, like the signal transmission delay, the postsynaptic potential, and the spike-afterpotential.

Wulfram Gerstner
Swiss Federal Institute of Technology

EPFL, IN-J
CH-1015 Lausanne
SWITZERLAND

MS17
Saddle-Node Bifurcations and Wave Propagation in Model Cortical Column Structures

A canonical model for a saddle-node bifurcation on a limit cycle will be described and related to column structures in the neocortex. A multi-layer network of such canonical models will be formulated and analyzed for the existence and stability of steady progressing wave solutions. Relations of these results to the propagation of activity in models of cortical barrel structures will be discussed.

Frank C. Hoppensteadt
System Science and Engineering Research Center
Arizona State University, Tempe, AZ 85287-7606

MS17
Rhythms and "Lurching" Waves in the "Sleeping" Thalamic Slice

Sleep spindle rhythms are generated in the thalamus. They can also occur spontaneously in an isolated "slice" of thalamic tissue, where interesting wave-like behavior is also observed. Current hypotheses for the neural basis of these rhythms will be outlined, and neural network models that simulate the rhythms will be presented. The nonlinear dynamics of single cells, and of the synaptic coupling between the excitatory (thalamocortical relay) and inhibitory (reticular nucleus) cells, will be described for these Hodgkin-Huxley-like models coupled in a 1-D chain architecture. In this system, coupling via synaptic inhibition plays a key role in rhythmogenesis and in wave propagation. The network has a stable resting state but a localized stimulus can initiate oscillatory activity. The activity spreads as a front with a "lurching" type propagation; in each cycle a discrete number of silent cells are recruited to join the population rhythm.

John Rinzel
National Institutes of Health, Bethesda, MD

Xiao-Jing Wang
Brandeis University
Waltham, MA

David Golomb
Ben-Gurion University
Beer-Sheva, Israel

MS17
Image Segmentation Based on Oscillatory Correlation

We consider a recent model for image segmentation based on neural oscillations. The model consists of a locally excitatory globally inhibitory oscillator network. We show both analytically and numerically that the network rapidly achieves both synchronization within blocks of oscillators that are stimulated by connected regions and desynchronization between different blocks. We further extend the model so that it is able to remove noisy regions from an image. The analysis naturally leads to a computer algorithm, which is applied to segmenting real, gray-level images.

David Terman
Ohio State University, Columbus, Ohio

DeLiang Wang
Ohio State University
Columbus, Ohio

MS18
Singular Limits of Phase Equations for Patterns Far from Threshold

We introduce a hyperviscous regularization of the phase diffusion equation which models the behaviour of patterns in extended systems far from threshold. In analogy to viscosity limits of Burgers' equation one finds that the associated viscosity limits of our regularization can produce weak solutions of the unregularized equation which effectively are single-valued truncations of the multi-valued phase diffusion solutions. We describe some generic types of defects that are found in these weak solutions. A complete description of the limits can be given when the boundary data is single-valued. We also describe some extensions to multi-valued boundary data, incorporating twist, which are needed to realize disclinations in the viscosity limit.

Nicholas M. Ercolani
University of Arizona, Tucson, AZ

Robert Indik
University of Arizona, Tucson, AZ

Alan Newell
University of Warwick, ENGLAND

Thierry Passot
Observatoire de Nice, FRANCE

MS18
Self-Replicating Spots

The self-replicating spot is a particle–like solution that occurs in reaction–diffusion systems. A spot grows until reaching a critical size at which time it divides in two. The two resulting spots again grow and divide. They propagate and deform on a slow time scale. Eventually they become unstable to perturbations on the fast time scale and divide. I will present an asymptotic analysis reflective of the above discussion.

John Pearson
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Los Alamos National Laboratory, Los Alamos, NM

MS19
Critical Behavior of the Distribution of Optimal Paths

The distribution of paths for large fluctuations away from a stable state is investigated. Singular features of the pattern of most probable (optimal) paths in non-equilibrium systems are revealed. We demonstrate critical broadening of the distribution of the paths coming to a cusp point that represents the simplest generic singularity of the optimal paths pattern. The critical behavior is shown to be described by a Landau-type theory. The problem of optimal

control of large fluctuations is discussed.

Mark I. Dykman and Vadim N. Smelyanskiy
Michigan State University, East Lansing, MI

MS19
Periodic Modulation of the Rate of Noise-Induced Escape through an Unstable Limit Cycle

Suppose that a bistable, one-dimensional continuous dynamical system is periodically driven in such a way that its attractors become distinct limit cycles: stable states of periodic vibration. Suppose that the system is additionally driven by weak noise. The noise may induce transitions between the two limit cycles. In the limit as the noise strength tends to zero, to leading order the frequency of these transitions falls off exponentially. We show that asymptotically, the transition rate includes a multiplicative factor that is periodic in the logarithm of the noise strength. Our analysis is based on a semiclassical approximation to the stationary probability density of the driven system, and applies both to the case of white noise and Markovian dichotomous noise.

Robert S. Maier
University of Arizona, Tucson, AR

MS19
Signal Enhancement by Large Fluctuations

The role of large fluctuations in mediating signal/noise enhancement of weak periodic signals in two different contexts will be discussed: *heterodyning*, with applications to electronics and nonlinear optics; and underdamped *zero-dispersion* systems, with applications to SQUIDs (superconducting quantum interference devices), relativistic oscillators and particle accelerators. In each case, large fluctuations can give rise to pronounced amplification of both the signal and the signal/noise ratio, much as occurs in classical stochastic resonance.

Peter V.E. McClintock
Lancaster University, Lancaster, UK

MS19
The Stochastic Manifestations of Chaos

Many aspects of the dynamics of random walks and Brownian motion can be understood using techniques of classical and quantum chaos theory. Symmetry breaking boundaries or coupling between degrees of freedom can lead to mutual repulsion of decay rates and a change of rate of approach to equilibrium. Whether or not these effects manifest themselves in the stochastic system depends on the size of the diffusion coefficient.

Linda E. Reichl
University of Texas, Austin, TX

MS20
Computation of Heteroclinic Two-Dimensional Invariant Manifold Interactions

We present and discuss alternative approaches to computing two- dimensional (un)stable manifolds of steady states and limit cycles of saddle-type; these are partially motivated from fluid interface evolution computations. We illustrate such techniques by computing, visualizing, and understanding global bifurcations involving the heteroclinic interaction of two-dimensional manifolds of different equilibria and/or limit cycles in a variety of three-dimensional systems.

Mark E. Johnson
Princeton University, Princeton, NJ

Michael S. Jolly
Indiana University, Bloomington, IN

Ioannis G. Kevrekidis
Princeton University, Princeton, NJ

John Lowengrub
University of Minnesota, Minneapolis, MN

MS20
Computing Invariant Manifolds of Saddle-Type

The computation of stable and unstable manifolds has mainly been done for hyperbolic fixed points. However, normally hyperbolic invariant manifolds also have stable and unstable manifolds, the knowledge of which promises much insight in the dynamics. Using an adaptation of the graph transform technique, we compute normally hyperbolic invariant manifolds of saddle-type and, subsequently, their stable and unstable manifolds.

Hinke Osinga
The Geometry Center
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MS20
Computing Stable Sets of Noninvertible Mappings

For diffeomorphisms, every point has a unique preimage and it is straightforward to compute one-dimensional stable manifolds of periodic points. For non-invertible mappings, however, some points have multiple preimages; others may have no preimages. This makes the computation of stable sets (the generalization of stable manifolds) difficult, because accurate computations require global knowledge about the way the mapping folds phase space. In this talk we geometrically analyze the folding and use this information to construct an algorithm for computing stable sets.

Frederick J. Wicklin
Chia-Hsing Nien
Dept. Mathematics Department and Geometry Center, U. Minnesota

MS20
Stable and Unstable Manifolds of Halo Orbits in the Circular Restricted Three-Body Problem

Recently, the space science community has shown an interest in sending scientific missions to the vicinity of the collinear Earth-Sun libration points. A fuller understanding of the geometry of the phase space of the circular restricted three-body problem could provide new possibilities for baseline trajectory design. For this purpose, we compute families of halo orbits in the circular restricted three-body problem. The stable manifolds of these orbits provide low energy trajectories to the orbits. We present an algorithm for the computation and visualization of these

orbits and their stable and unstable manifolds.

Robert Thurman
University of Minnesota, Minneapolis, MN

Patrick Worfolk
University of Minnesota, Minneapolis, MN

MS21
Dynamical Properties of Two-Dimensional Josephson-Junction Arrays*

Two-dimensional arrays of Josephson junctions are potentially useful as high-frequency oscillators, as well as providing an experimental system for studying the stability of coupled non- linear oscillators. Our experiments and simulations show that the stability of arrays is strongly influenced by parameters of the junctions in the array and the load-coupling circuit. In our best designs, a significant fraction of the theoretical maximum power has been coupled to a detector.
Work supported in part by the Air Force Office of Scientific Research under Grant No. F49620-92-J-0041.

A.B. Cawthorne, P. Barbara, and C.J. Lobb
University of Maryland
College Park, MD

MS21
Generation of Submillimeter Wave Radiation Using Linear Phase-Locked Josephson Junction Arrays Recent results on the generation of submillimeter wave radiation using Josephson junctions arrays are discussed. Power levels approaching 1/2 milliwatt for frequencies above 400 GHz have been achieved. It appear that instabilities arising in the individual junctions are an important limitation on the junction's maximum critical current and thus on the array power.

James Lukens
State University of New York

MS21
Josephson Junction Arrays: Practical Devices and Non-linear Dynamics Experiments, numerical simulations and analysis are used to investigate dynamical states in arrays of Josephson junctions which are governed by the discrete sine-Gordon equation. We will discuss their potential for microwave applications as well as for models of coupled physical systems, and the types of experiments and systems that have been studied. Experimental evidence will be shown for dynamical effects such as parametric instabilities of whirling modes, phase-locking of kinks to linear waves, phase-locking between rows, and dynamical checkerboard states.

Terry P. Orlando
Massachusetts Institute of Technology
Cambridge, MA

MS22
Bäcklund Transformations of Knots of Constant Torsion

The Bäcklund transformation for the sine-Gordon equation can be adapted to give a transformation on space curves that preserves constant torsion. We study its effects on closed curves (in particular, elastic rods) that generate multiphase solutions for the vortex filament lfow (also known as the Losalized Induction Equation). In doing so, we obtain initial data for multiphase solutions of the LIE representing a large number of knots types.

Annalisa Calini,
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University of Charleston,
66 George st.,
Charleston SC 29424
Thomas Ivey,
Department of Mathematics,
Case Western Reserve University,
Cleveland OH 44106

MS22
Homotopies and Knot Types of Elastic Rods

Elastic rods can be characterized either as space curves which are critical for some combination of length, total torsion, and elastic energy, or as solutions of the Localized Induction Equation that move by a screw motion. Based on work of Langer and Singer, we show that every torus knot type is realized by an elastic rod. Furthermore, there exist one-parameter families of elastic rods connecting the m-covered circle with the n-covered circle whenever m and n are coprime.

Thomas Ivey,
Department of Mathematics,
Case Western Reserve University,
Cleveland OH 44106

MS22
Geometric Realizations of Fordy-Kulish Integrable Systems, Sym-Pohlmeyer Curves, and Related Variation Formulas. Part I

A method of Sym and Pohlmeyer, which produces geometric realizations of many integrable systems, is applied to the Fordy-Kulish "generalized non-linear Schrödinger equations" associated with Hermitian symmetric Lie algebras. Such equations are seen here to correspond to arclength-parametrized curves evolving in Euclidean and other spaces, generalizing the "localized induction model" of vortex filament motion. In this context, a "geometric recursion operator" is introduced, and a compact formula for the variation of "natural curvatures" in terms of this operator is derived. Applying the above formalism, hierarchies of evolution equations are obtained for curves evolving in n-dimensional Euclidean space, with curvatires satisfying an equation in a "generalized m-KdV hierarchy". A special case appears to be related to recent constructions of Doliwa and Santini, and may help illuminate certain features of the latter.

Joel Langer, Department of Mathematics, Case Western Reserve University, Cleveland OH 44106
Ron Perline, Department of Mathematics and Computer Science, Drexel
University, Philadelphia PA 19104

MS22
Geometric Realizations of Fordy-Kulish Integrable Systems, Sym-Pohlmeyer Curves, and Related

Variation Formulas. Part II

A method of Sym and Pohlmeyer, which produces geometric realizations of many integrable systems, is applied to the Fordy-Kulish "generalized non-linear Schrödinger equations" associated with Hermitian symmetric Lie algebras. Such equations are seen here to correspond to arclength-parametrized curves evolving in Euclidean and other spaces, generalizing the "localized induction model" of vortex filament motion. In this context, a "geometric recursion operator" is introduced, and a compact formula for the variation of "natural curvatures" in terms of this operator is derived. Applying the above formalism, hierarchies of evolution equations are obtained for curves evolving in n-dimensional Euclidean space, with curvatires satisfying an equation in a "generalized m-KdV hierarchy". A special case appears to be related to recent constructions of Doliwa and Santini, and may help illuminate certain features of the latter.

Joel Langer,
Department of Mathematics,
Case Western Reserve University,
Cleveland OH 44106
Ron Perline,
Department of Mathematics and Computer Science,
Drexel University, Philadelphia PA 19104

MS23
Synaptically Induced Bistability and Transition to Repetitive Activity

Many model cortical cells undergo a transition from rest to repetitive activity as some parameter varies via a saddlnode loop bifurcation. We examine how the temporal properties of excitatory synapses influence the transition from a single transmitted pulse to repeated activity. The transition behavior can be understood via simplified dynamical equations and an analysis of these equations. Two cases are considered: (i) self-excitation and (ii) a pair of mutually coupled cells. A map is numerically computed showing an apparent chaotic transition between states.

Bard Ermentrout
and
Jim Uschock
Department of Mathematics
University of Pittsburgh
Pittsburgh, PA 15260

MS23
The Role of Spike Adaptation in Shaping Spatiotemporal Patterns of Activity in Cortex

We study analytically and numerically cortical network models to show that synchronized bursts or traveling pulses of activity can emerge in cortex from the "conspiracy" between spike adaptation and cortical excitatory feedback. The bifurcations leading to these states are studied. The properties of the emergent spatiotemporal activity patterns are analyzed. In particular, the bursting period is shown to depend mainly on the adaptation time constant. Possible functional roles of the traveling pulses are examined.

D. Hansel, Centre de Physique Théorique, CNRS-UPR014, Ecole Polytechnique, 91128, Palaiseau, France

MS23
Pattern Generation by Two Coupled Time-Discrete Neural Networks with Synaptic Depression

We discuss the oscillatory activity of a random neural network with purely excitatory connections and use dependent synaptic depression. The work is motivated by measurements in slice cultures of embryonic rat spinal cord. Modeling two symmetrically coupled networks, one observes inphase, antiphase, quasiperiodic or phase-trapped oscillations. These different activity patterns are obtained by adapting the time constant of the synaptic depression. The mathematical methods we use are bifurcation theory and average phase difference theory.

Walter Senn
Institute of Informatics, University of Bern, Switzerland

Jürg Streit
Department of Physiology,
University of Bern, Switzerland

MS23
Modeling Cortical 40 Hz Oscillations: Pacemaker Neurons and Synaptic Synchronization

Fast neuronal oscillations (gamma, 40 Hz) have been observed in the neocortex and hippocampus during behavioral arousal. In this talk I shall review experimental results and present thereotical studies that suggest how such a rhythm may emerge in cortical networks. It is shown that the rhythm can be generated by pacemaker neurons, which either display subthreshold membrane oscillations or bursting at around 40 Hz. Then, I shall discuss synaptic mechanisms for network synchronization of this rhythm, with an emphasis on recurrent inhibition.

Xiao-Jing Wang
Physics Department and Center for Complex Systems,
Brandeis University, Waltham, MA 02254

MS24
ODE Architect: CODEE's Multimedia Package

The introductory DE course is evolving very rapidly and relying more and more on technology. Powerful computer platforms and software make it possible for students to explore the properties of dynamical systems and have fun doing it. ODE Architect, an inexpensive multimedia solver/modeler, developed by the CODEE consortium, runs on a PC and teaches students modeling concepts in a supportive, stress-free environment. We explore its features via modeling modules that overlay a state-of-the-art solver.

Robert L. Borrelli
Harvey Mudd College, Claremont, CA

MS24
How to Make a Pendulum Do Anything You Want

Although the forced pendulum is one of the most standard differential equations one encounters in calculus classes, the actual behavior it predicts can be most complicated. We'll show that for appropriate forcing and damping, we can find initial conditions that lead to any preassigned sequence of gyrations. The instability of these motions has a counterpart – the pendulum is highly controllable.

John H. Hubbard
Cornell University, Ithaca, NY

MS24
Visualization and Verification, with Mathematica, of Solutions to Differential Equations

Dan Schwalbe and I have written a comprehensive Mathematica package for the visualization of solutions to DEs. Innovative ideas include shaded nullcline regions,curved fish-like shapes to generate flow fields. In addition to presenting the package, I will show how Mathematica can be used to check on the correctness of numerical solutions, and discuss some complicated examples, such as the unstable motion of a book thrown into the air with certain initial spins.

Stan Wagon
Macalester College, St. Paul, MN

MS24
Teaching ODE's with the WWW and a Calculator Based Laboratory

Teaching Differential Equations using the World Wide Web with a combination of hands-on experimentation (using the Texas Instrument Calculator Based Laboratory), JAVA applets, and a Computer Algebra System – all orchestrated by a browser like Netscape.

Frank Wattenberg
Carroll College and Montana State University, Helena, MT

MS25
Curve Dynamics and Gene Regulation

The motion of DNA plays an important role in gene regulation. We present three complementary mathematical models for the initiation of transcription, in which DNA motion is incorporated into the model using Langevin dynamics, Monte-Carlo simulations and from energy considerations.

Gadi Fibich
UCLA, Los-Angeles, CA

Danny Petrasek
UCLA, Los-Angeles, CA

Isaac Klapper
Montana State University, MO

MS25
Nonlinear Dynamics of Elastic Filament

The Kirchoff model provides a well established framework to study the dynamics of thin elastic filament. A new perturbation scheme is introduced to study the stability and dynamics of static solutions after bifurcation. A linear analysis of the static solutions enables us to describe the instabilities that filaments undergo when twist or tension is varied. At the bifurcation point where the filament becomes unstable, a weakly nonlinear analysis can be carried out and an amplitude equation for the post-bifurcation dynamics is obtained. The static solutions of a variety of problems, including the twisted planar ring, the straight rod and helical filaments with intrinsic curvature, are analyzed by this method.

Alain Goriely
University of Arizona, Tucson USA

Michael Tabor
University of Arizona, Tucson USA

MS25
Removing the Stiffness of Curvature in 3-D Filament Calculations

We present a new formulation for computing the motion of 3-D filaments with curvature effect. The curvature effect introduces high-order terms into the dynamics. This leads to severe stability constraints for explicit time integration methods and makes the application of implicit methods difficult. Our new formulation completely removes the severe time stability constraint, and gives an efficient implicit method. Applications to motion by mean curvature and some elastic rod model problem will be given.

Thomas Y. Hou
Applied Mathematics, Caltech

Issac Klapper
Dept. of Mathematics
UCLA

Hui Si Applied Mathematics
Caltech

MS26
The Role of Attractors in Stochastic Bifurcation Theory

Inspite of great efforts in recent years, bifurcation theory of dynamical systems in the presence of noise is still in its infancy. There are few rigorous general theorems and criteria, and many phenomena have been "proved" only by computer simulations, or for particular models. We report on progress made by utilizing the concept of a random attractor recently introduced by Crauel, Debussche, Flandoli and Schmalfuß. Its existence can be assured under quite general conditions. Since a random attractor carries all invariant measures (Crauel), the bifurcation of the attractor gives us information about the bifurcation of invariant measures. Several examples in dimension one and two are considered.

Ludwig Arnold
Institute for Dynamical Systems
University of Bremen

MS26
Bifurcation Theory for Stochastic Differential Equations

We study a parametrised family of multidimensional nonlinear stochastic differential equations fixing 0. Suppose the parameters are varied in such a way that the Lyapunov exponent λ for the associated linear system changes sign from negative to positive. The stable fixed point 0 becomes unstable and a new stationary probability measure μ, with 'most' of its mass 'near' 0, appears. We give some quantitative results on μ valid for small positive values of λ.

Peter H. Baxendale,
Department of Mathematics,
University of Southern California,
Los Angeles, CA 90089-1113,
U.S.A.

MS27

Some Experiments on Nonstationary Vibrations in a Single Degree-of-freedom Nonlinear System

An experimental rig was constructed to observe the response of a thin cantilever beam system undergoing nonstationary excitation. Initially, the beam was configured so that under stationary, sinusoidal excitation, chaotic responses were observed in a region of frequencies. The beam was also subjected to swept sinewave excitation, sweeping through this chaotic region, in order to discover how the sweep rate affected the response characteristics. The faster the sweep rate, the smaller the frequency region over which chaotic behavior was observed. Oscillations in the response amplitude, similar to those found in similar experiments on linear systems, were also observed.

Anil K. Bajaj, Mark Hood and Patricia Davies
School of Mechanical Engineering
Purdue University
W. Lafayette
Indiana 47907

MS27

Some Experiments on Nonstationary Vibrations in a Single Degree-of-freedom Nonlinear System

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Anil K. Bajaj, Mark Hood and Patricia Davies
School of Mechanical Engineering
Purdue University
W. Lafayette
Indiana 47907

MS27

Weakly Unstable Systems in the Presence of Neutrally Stable Modes

Near the onset of a linear instability, the nonlinear evolution of the mode amplitudes can be described using an expansion in the amplitude of the unstable modes. Since the growth rates are very small near onset, nonlinear effects often act to saturate the instability before the amplitudes grow appreciably; for this reason such expansions have proved a powerful tool for studying the nonlinear states emerging from the bifurcation. In addition, the prototypical dissipative examples share another characteristic: except for the unstable modes, all other linear modes are exponentially damped. In particular, there are no neutrally stable modes with nonlinear couplings to the unstable modes. If such neutral modes are present, the amplitude equations for the unstable modes, i.e. normal forms on the unstable manifold, can have very different features. We discuss several illustrative examples: the normal form for a Hopf/saddle node mode interaction, the Vlasov equation from plasma physics, and a continuum model for the Kuramoto system of phase oscillators. The normal forms in these examples exhibit singularities that we interpret as evidence of new nonlinear scalings and also show no evidence of being finitely determined. This research is being pursued in collaboration with K.T.R. Davies and A. Jayaraman.

J.D. Crawford
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University of Pittsburgh
Pittsburgh, PA 15260
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MS27

Weakly Unstable Systems in the Presence of Neutrally Stable Modes

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J.D. Crawford
Dept. of Physics
University of Pittsburgh
Pittsburgh, PA 15260

MS27

Accurate Phase After Slow Passage Through Subharmonic Resonance

The slow passage through subharmonic resonance is analyzed for a periodically forced conservative system with weak damping. Multiphased averaging fails, requiring a subharmonic resonance layer. By matching to sufficiently high order, a new more accurate jump in the average energy across a subharmonic resoance layer is obtained. It is shown that the correct phase of the strongly nonlinear oscillator after subharmonic resonance may be obtained using a time shift and a constant phase adjustment.

Jerry D. Brothers
Raytheon E-Systems
Garland, TX

Richard Haberman
Southern Methodist University
Dallas, TX

MS27
Slow Evolution Near Families of Stable Equilibria of Hamiltonian Systems

The problem of slow evolution in Hamiltonian systems is formulated as a singularly perturbed initial-value problem. The conditions for a family of equilibria to represent asymptotic solutions to the full evolution equations are given. These conditions break down at a critical point for orbits of the unperturbed system. Examples from fluid dynamics and astrophysics are given to motivate consideration of particular kinds of critical points and normal forms, and evolution through families containing these critical points is discussed.

Norman R. Lebovitz
University of Chicago, Chicago, IL

MS28
Discovering the Mysteries of Swimming Microorganisms on the Beaches of Rio

Determining the mechanism for self propulsion is fundamental in the u nderstanding of the relationship between motile bacteria and their environment. The fine structures and detailed motions of many bacteria are too small to be observed under a light microscope. Clever experiments are ultimately necessary to determine the mechanism. We present some mathematical models and predictions which help biologists in designing such experiments.

Kurt Ehlers
L.N.C.C., Rio de Janeiro

MS28
A Spectral Method for Stokes Flows and Applications to Microswimming

We present the spectral properties of the propulsion operator $P : \vec{U} \rightarrow \vec{F}$, relating velocity fields to surface force fields along the boundary of a domain (possibly multiply-connected). Numerical methods based on the boundary integral approach are discussed, with examples. For microswimming applications, it is important to relate the eigenvalues λ_m and λ_n to the curvature coefficients F_{mn}. We explain our conjectures and how they are related to the question of optimizing the efficiency.

Jair Koiller, L.N.C.C.
Laboratorio Nacional de Computacao Cientifica, Brazil Rio de Janeiro, Brazil

Joaquin Delgado
U.N.A.M., Mexico City, Mexico

Marco Raupp
Laboratorio Nacional de Computacao Cientifica, Brazil Rio de Janeiro, Brazil

MS28
Geometry of Microswimming

Shapere and Wilczek observed that low-Reynolds number swimming can be described in terms of the holonomy of a certain connection (gauge field), the Stokes connection. We show that this connection is in fact a "mechanical connection":it can be defined solely in terms of the "physically correct metric" on configuration space. The quadratic form for this metric measures the power output of a given shape deformation, and the fact that the metric is Riemannian is a consequence of a reciprocity theorem for the Stokes equations.

Richard Montgomery
UCSC, Santa Cruz, CA

MS28
Self-Propulsion of Spherical Swimmers Using Surface Deformations

Strategies for swimming adopted by microorganisms must conform to the physical principles of self-propulsion at low Reynolds numbers. Here we present an analysis that relates the translational and rotational speeds to the surface motions of a swimming object, and, for swimming spheres, makes evident novel constraints on potential mechanisms for propulsion. We consider strategies for the swimming of a cyanobacterium, an organism whose motile mechanism is unknown, by considering incompressible streaming of the cell surface and oscillatory, tangential surface deformations. Finally, the efficiency of swimming is discussed.

Aravi Samuel
Harvard, Cambridge, MA

Howard Stone
Harvard, Cambridge, MA

Howard Berg
Harvard, Cambridge, MA

MS29
On the Influence of Viscosity on Riemann Solutions of Nonlinear Conservation Laws

In this talk I will show how existence, uniqueness and construction of Riemann solutions are affected by the precise form of viscosity which is used to select shock waves admitting a viscous profile. The results are obtained in the context of nonlinear 2×2 systems of conservation laws that change type. The approach is based on a study of codimension-1 bifurcations that distinguish between Lax shock waves with and without a profile. I will present "generic" situations in which viscous Riemann solutions differ from Lax solutions.

Sunčica Čanić
Department of Mathematics
Iowa State University
Ames, IA 50011

MS29
An Application of Vectorfield Bifurcation to Conservation Laws that Change Type

Viscous perturbations are used in conservation law theory to validate shock admissibility criteria. In this context, the problem of determining which shocks are admissible reduces to finding heteroclinic orbits in a related dynamical system. It is instructive to apply this method to systems which change type (are not hyperbolic for all states). One example of such a system is a standard model for steady transonic flow; change of type also arises in models for unsteady flows. When a perturbation based on physical viscosity is applied to the steady transonic flow equations, the dynamics are described by a codimension one bifurcation near the sonic line. The standard admissibility condition is recovered in this case. However, a standard, and plausible,

choice for viscous perturbation of unsteady systems leads to a variant of the codimension two Takens-Bogdanov vectorfield bifurcation. One conclusion is that admissibility conditions in this case are sensitive to the coefficients in the viscous perturbation.

Barbara Lee Keyfitz
Department of Mathematics
University of Houston
Houston, TX 77204-3476

MS29
The Role of Polycycles in Nonuniqueness of Riemann Solutions

We discuss how homoclinic orbits, two-saddle cycles, and three-saddle cycles in the planar dynamical systems associated with traveling waves for viscous conservation laws lead to nonuniqueness of solutions of Riemann problems. The bifurcation analysis involves codimension three phenomena, including degenerate nilpotent singularities of the saddle type, studied by Dumortier, Roussarie, Sotomayor, Żoładek, and Rousseau. We demonstrate that these polycycles occur for a class of conservation laws important in petroleum reservoir simulation.

Arthur Azevedo
Universidade de Brasilia
Brasilia, Brazil

Dan Marchesin
Instituto de Matemática Pura e Aplicada
Rio de Janeiro, Brazil

Bradley Plohr
Departments of Mathematics and of Applied Mathematics and Statistics
University at Stony Brook
Stony Brook, NY 11794-3651

Kevin Zumbrun
Indiana University
Bloomington, IN

MS29
Riemann Problem Solutions of Codimensions 0 and 1

A Riemann solution is *structurally stable* if any perturbation of the left state, right state, and flux function yields a nearby Riemann solution with the same sequence of wave types. For systems of two conservation laws in one space dimension, we describe a large class of structurally stable Riemann solutions. We also describe how to study systematically the codimension one Riemann solutions that separate them. They give rise to various folds, "joins," and frontiers of the Riemann solution manifold.

Stephen Schecter
Department of Mathematics
North Carolina State University
Raleigh, NC 27695-8205

Dan Marchesin
Instituto de Matemática Pura e Aplicada
Rio de Janeiro, Brazil

Bradley Plohr
University at Stony Brook
Stony Brook, NY

MS30
Low Frequency Variability in Ocean Circulation Models Driven by Constant Forcing

An example is given of low frequency variability in an ocean circulation model driven by constant surface forcing. Particular attention is paid to the role of the internal wave dynamics and the dependence of the variability on the mean state.

Richard J. Greatbatch
Department of Physics and Physical Oceanography
Memorial University of Newfoundland
St. John's, Newfoundland, Canada, A1B 3X7

MS30
Mathematical and Computational Issues in the Double Gyre Model

Although the oceanic double-gyre model has been the subject of continuous study for over two decades, a number of basic mathematical and computational issues remain unresolved. I will review and discuss issues related to the consistency and convergence of models with free- or partial-slip boundary conditions, and will provide examples of the effect of alternate discretization strategies and alternate domain geometries on the structure of the western boundary layer. I will conclude with a presentation of very high resolution results with special attention paid to resolution of the vorticity discontinuity of the free jet, and its influence on the existence of multiple stationary states in the system.

John D. McCalpin
Silicon Graphics Computer Systems
Mountain View, CA

MS30
Low-Frequency Variability of Wind-Driven Ocean Gyres

We consider the equilibrium dynamics of a mid-latitude ocean in an enclosed basin driven by a steady surface wind stress. The Reynolds number Re associated with the horizontal (eddy) viscosity can be viewed as a control parameter for a bifurcation sequence that begins with a steady circulation. The first bifurcation is due to a mesoscale instability of this circulation, giving rise to the a broad-band spectrum of the now familiar mesoscale eddies as Re increases further. A further bifurcation occurs due to fluctuations with even longer periods and larger spatial scales (than the mesoscale), which can therefore be consider an aspect of climate variability for the Earth. We analyze this latter class of fluctuations, using Principal Orthogonal Decompositions, and diagnose their essential dynamical balances.

Pavel S. Berloff
IGPP, UCLA, Los Angeles, CA 90095-1567

James C. McWilliams
IGPP, UCLA, Los Angeles, CA 90095-1567

MS30
Low Frequency Variability in the Reduced-Gravity

Shallow Water Model

Century-scale simulations of the steady wind-forced double gyre circulation using a reduced-gravity shallow water model reveal significant levels of low-frequency variability. We will discuss various methods of analyzing the resulting short and noisy time series that take into account the different physical processes that are represented.

Balu Nadiga

Len Margolin

Darryl Holm
Los Alamos National Laboratory, Los Alamos, NM 87544

MS31

New Measures of Coherence in Disordered and Noisy Arrays of Coupled Phase Oscillators

Arrays of coupled phase oscillators are used to describe the dynamics of systems arising in such diverse areas as electronics, biology and chemistry. Of importance is whether the oscillators are phase locked, their phase relationship, and the effects of oscillator disorder and noise. We have applied bi-orthogonal decomposition methods to the data resulting from the arrays and developed new measures to describe the dynamics. Compared to more traditional measures, in many cases our results show increase sensitivity to changes in the system dynamics.

Thomas W. Carr
Department of Mathematics
Southern Methodist University
Dallas, TX 75275-0156

Ira B. Schwartz
Special Project for Nonlinear Science
Naval Research Laboratory
Washington, D.C. 20375

MS31

Analysis of Extensive Chaos by the Karhunen-Loeve Decomposition and by A Hierarchy of Unstable Periodic Orbits

An important challenge is to develop theoretical, and hopefully practical, ways to characterize the rich spatiotemporal dynamics often found in large, nontransient, high-dimensional nonequilibrium systems. I review recent work (in collaboration with Scott Zoldi) in which the Karhunen-Loeve decomposition and the hierarchy of unstable periodic orbits have been investigated to determine what kinds of insights they can provide about EXTENSIVE CHAOS, for which the attractor dimension grows in proportion to the physical volume of the system.

Henry Greenside
Duke University,
Durham, NC

MS31

Modeling The Dynamics of Wall Bounded Turbulece

Turbulent channel flow, which is homogeneous in two spatial dimensions, is probably the simplest example of genuine turbulence. It is nevertheless too complex to be adequately described low dimensional dynamical systems. A survey will be presented of new (and old) attempts to overcome this challenge.

Larry Sirovich
Div. Appl. Math, Brown U. & Lab. Appl. Math, CUNY/Mt Sinai

MS31

Analysis and Control of Spatio-Temporal Chaos in Reaction-Diffusion Process

Karhunen-Loeve decomposition is done on a chaotic spatio-temporal solution of a reaction-diffusion model exhibiting bursting. It is shown that unstable states can be maintained by performing fluctuations of the concentration at the boundaries, while monitoring the dynamics of the time series obtained by projecting the main Karhunen-Loeve mode on the solution as the reaction-diffusion equation is solved in time. We also discuss the bifurcations of a low-dimensional model for the same reaction-diffusion process obtained by using a Galerkin projection of the dominant Karhunen-Loeve modes back onto the nonlinear partial differential system.

Ioana Triandaf
Science Applications International, Corp, McClean, VA

MS32

Stability of the Stationary States of the Elastic Rod Model Under an Applied External Force that Represent Configurations of DNA in Living Cells

Solutions for the stationary states of the elastic rod model under an externally applied bending force have been derived. The solutions represent the helical (11nm fiber) and superhelical (30nm fiber) configurations of DNA. In vivo the bending force arises from electrostatic interactions between the histone octamer and DNA; thus, electrostatic interactions that produce the bending forces have been determined. The interactions are chosen so as to stabilize the 11nm and 30nm stationary state solutions of the elastic rod.

Thomas Connor Bishop
University of California, Berkeley, CA

John E. Hearst
University of California, Berkeley, CA

MS32

A Combined Wormlike-Chain and Bead Model for Dynamic Simulations of Long DNA

A new model for simulating dynamic properties of long DNA is presented, combining features of both wormlike chain and bead models. Our goal is to use the model for Langevin dynamics simulations of both linear and closed circular DNA. The energy of the model chain includes stretching, bending, twisting and electrostatic components. Beads are associated with each vertex of the chain and specify hydrodynamic properties of the DNA. Careful parameterization of the model is presented. In addition, we modified the second-order Brownian dynamics (BD) algorithm to make it more efficient for our model. Equilibrium properties obtained from our dynamic simulations are compared with results of Monte Carlo simulations. Very good agreement is obtained for distributions of writhe and the radius of gyration. Our BD results for the translational diffusion constant agree very well with the experimental

results as well. We also obtained very good agreement between corresponding rotational diffusion constant. Finally, an illustrative dynamic result on DNA slithering is presented.

Hongmei Jian
New York University, New York, NY

Alexander Vologodskii
New York University, New York, NY

Tamar Schlick
New York University, New York, NY
The Howard Hughes Medical Institute

MS32
Modeling Stable Configurations of Protein-bound DNA Rings

The precise geometry of protein-DNA complexes has been shown to be a significant factor in the proper function and regulation of the genetic machinery. However, the effect of nucleosome formation, a packaging motif which entails the superhelical wrapping of DNA about a core of eight histone proteins, on the configuration of the rest of the DNA chain is not clear. Precise three-dimensional images of long DNA chains bound to histone-type proteins are difficult to obtain by experimental means. Presently, to visualize DNA minichromosomes, constrained by the presence of nucleosomes, we have stochastically determined the minimum energy configurations based upon a library of equilibrium structures. Here, the behavior of the protein-free segments of each DNA chain is likened to that of an elastic rod with equivalent end constraints. Our results suggest that these interactions may play a significant role in activating genetic events by dramatically altering the configuration of the duplex through minor adjustments in the path of the DNA on the protein core, the shape of the core itself, and the location of the complex along the chain contour.

Jennifer A. Martino.
Rutgers University, Piscataway, NJ

MS32
Stability in Continuum Models of DNA Minicircles

Stability results based on a constrained variational principle will be presented for elastic loops loaded with varying amounts of imposed twist. The underlying variational structure is employed to predict exchanges of stability based on the shape of the solution branch in a 'distinguished bifurcation diagram', namely a plot of twist moment vs. end angle. The shapes of the solution branches in this distinguished diagram, and therefore the stability properties of equilibria, depend upon the material parameters of the rod. These stability results are used as part of a study of DNA mini-circles using an elastic rod model with experimentally motivated parameters for bending stiffness, twisting stiffness, and the curved unstressed shape. Computations with the boundary value problem solver AUTO, the visualization tool PCR, and a numerical implementation of an appropriate conjugate point test allow the determination of the stability properties and index of each cyclized equilibrium of the DNA.

Kathleen A. Rogers
University of Maryland, College Park, MD

Robert S. Manning
University of Maryland, College Park, MD

John H. Maddocks
University of Maryland, College Park, MD

MS33
Propagation of Nonsoliton Pulses in Long Optically Amplified Transmission Lines

Current generation telecommunications systems require single channel data rates of 5-20 GB/s and may be as long as 9000 km. There may be many channels at different wavelengths on a single fiber. The digital data may be encoded in either soliton or nonsoliton pulses. One thing all these systems have in common is that their success depends critically on our understanding of how the interplay of dispersion and nonlinearity in the fiber determines the evolution of the pulses. The evolution of these signals is governed by the nonlinear Schrodinger equation. We will discuss the results of recent experiments where nonsoliton pulses were propagated in a transmission line with periodic dispersion changes.

Stephen Evangelides Jr.
AT&T Research
Holmdel, NJ 07733

Nonlinear Optical Phenomena in Periodic Structures

We consider optical waveguides that have a periodic spatial modulation of the refractive index. The inclusion of an intensity-dependent refractive index leads to such phenomena as pulse compression and soliton propagation. For active periodic structures, i.e., those with gain, we find an instability that leads to very high frequency self-pulsations.

Herbert G. Winful
EECS Department
University of Michigan
Ann Arbor, MI 48109

MS33
Modelocked Fiber Laser Simulation and Modeling

We discuss models of actively and passively modelocked lasers for communication applications. Comparison between the models and experiment are developed and analytical results are given.

J. W. Haus and G. Shaulov
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Rensselaer Polytechnic Institute
Troy, NY 12180-3590
J. Theimer
Rome Laboratory RL/OCPA
25 Electronics Ave.
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MS33
The Whitham Equations for Optical Communications in NRZ Format

We present a model of an optical communication system using high-bit-rate data transmission in the nonreturn-to-zero (NRZ) format over transoceanic distances. The system operates in the small group dispersion regime, and the model equation is given by the Whitham equations

describing the slow modulation of multi-phase wavetrains for the (defocusing) nonlinear Schrödinger (NLS) equation. The model equation has a hyperbolic nature, and certain initial NRZ pulse develops a shock. We then show how one can regularize solutions by choosing an appropriate Riemann surface where the Whitham equation is defined. The present analysis may be interpreted as an alternative to the method of inverse scattering transformation for the NLS solitons.

Yuji Kodama
Department of Electronics and Information Systems
Osaka University
2-1 Yamade-Oke
Suita Osaka 565, Japan

MS34
A Case Study of Topology Preserved in an Environment with Noise: Fluid Flowing Past an Array of Cylinders

Standard dynamical systems theory is based on the study of invariant sets. For area preserving models that incorporate noise, there are no bounded invariant sets. Our goal is to study the fractal structure that exists even with noise. The problem we investigate is fluid flow past two or more cylinders with small random disturbances.

Judy A. Kennedy Dept of Math. Sci.
Univ. of Delaware
Newark DE
19716-0001

MS34
Horseshoes and the Conley Index Spectrum

Let f:X to X be a continuous map. The Conley Index is defined for an isolating neighborhood. The talk will discuss how and when the Conley Index can be used to conclude that some power of f can be represented by the full shift on two symbols. In other words that f exhibits the dynamics of a horseshoe.

Konstantin Mischaikow
addressSchool of Math
Georgia Tech.
Atlanta Georgia
30332-0001

MS34
Stable Ergodicity and Stable Accessibility

Boltzmann's ergodic hypothesis - that ergodicity is a generic property of volume preserving dynamical systems - underlies statistical mechanics and much of physical thinking. Yet, in 1954, Kolmogorov showed that Boltzmann was wrong. The twist map is an area preserving diffeomorphism of the plane that is not ergodic, nor is any area preserving diffeomorphism that C^4 approximates it, due to the persistence of the invariant KAM circles. Nevertheless, it is our contention that Boltzmann was more right than wrong: in the joint presence of hyperbolicity and KAM dynamics, hyperbolicity can overwhelm the KAM dynamics and produce robust statistics in the form of ergodicity. - joint work with Mike Shub

Charles C. Pugh
Mathematics Department
Univ of California, Berkeley
Berkeley, CA 94702

MS34
Crises: The Dynamics of Invariant Sets as a Parameter is Varied

"Basic sets" are sets that are invariant and have a dense trajectory (and are not contained in a larger such set). They can include attractors and the Cantor sets of horseshoes and periodic orbits. This talk will describe how basic sets change and collide and merge as parameters are varied. This is joint work with Kathleen Alligood.

James A. Yorke
I.P.S.T.
University of Maryland
College Park, MD 20742-2431

MS35
Mathematical Models of Stochastic Ratchets

We describe some simple mathematical models of directed motion resulting from the interplay of undirected random forces in an anisotropic environment. While some more elaborate versions of these ideas are used to model molecular motors in subcellular and molecular biology, the essential concepts are also being developed for possible applications in materials processing technology. In this talk we will show how even some simple mechanisms can generate complex, nonintuitive motions, and how their analysis can present interesting mathematical challenges.

Charles R. Doering
University of Michigan, Ann Arbor MI

MS35
The Bacterial Flagellar Motor: A New Mechanism for Energy Transduction

The bacterial flagellar motor is driven by a flux of ions between the cytoplasm and the periplasmic lumen. Here we show how an electrostatic mechanism can convert this ion flux into a rotary torque. We demonstrate that with reasonable parameters, the model can reproduce many of the experimental measurements.

Timothy C. Elston
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George Oster
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MS35
Is the Speed of a Molecular Motor Influenced by its Elasticity?

Biomolecular motors typically have elastic components, and the question arises whether such elasticity is important to the effective operation of the motor. This question will be considered within the framework of Brownian ratchet molecular motors. An idealized example will be discussed

in which a perfect Brownian ratchet motor pulls a "heavy" load, i.e., a load with a much smaller diffusion coefficient than that of the motor itself. The load is connected to the motor by an elastic tether, and a comparison is made of the two limiting cases of an infinitely stiff connection and an infinitely compliant one. An analogous (but unsolved) problem for the case of chromosome transport will also be briefly discussed.

Charles S. Peskin
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New York University (New York, NY 10012)
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MS36
Lagrangian and Eulerian transport: Are they related?

In experiments with fluid flows one often observes the motion of extended Eulerian structures, e.g., jets, eddies, or vortices. One has the general intuition that the transport of Eulerian structures is strongly related to particle transport. In this talk I describe the geometry of two-dimensional Eulerian transport and show that, in general, there is no relationship between Eulerian and Lagrangian transport. However, there exists such a relationship in the case of adiabatic flows. I discuss the application of these results to eddy-jet interactions.

George Haller
Brown University, Providence, RI

MS36
Transport in Quadratic Volume Preserving Maps

By analogy with the Henon map of the plane, we find the normal form for quadratic volume preserving maps in $\mathcal{R}^3$. We investigate the set of bounded orbits, using the transit time decomposition, following our work in Meiss, J. D. (1996). "Average Exit Time for Volume Preserving Maps." Chaos in press.

J.D. Meiss
University of Colorado, Boulder, CO

MS36
Degeneracies, Instabilities and Transport

In many applications underlying symmetries cause strong degeneracies which are only slightly broken in the real setting. These degeneracies lead to strong instabilities even in low dimensional systems in which usually partial barriers/barriers slow down/inhibit transport. Thus, the study of these singular mechanisms of instabilities is fundamental for understanding transport in real systems. Examples of this phenomena arising in an atmospherical model and in a Plasma model (a model describing the motion of a charged particle) will be presented.

Vered Rom-Kedar
Weizmann institute of Science, Rehovot, Israel

MS36
Scaling Properties of Distributions of Exit Time and Poincare Recurrences

For the Hamiltonian dynamical systems with chaotic dynamics transport is anomalous in general. On the basis of topological properties of the phase space it is possible to derive a renormalization group equation and express in an explicit form characteristic exponents for the probability density distributions of the exit time and the Poincare recurrence time.

G.M. Zaslavsky
New York University, New-York, NY

MS37
Bifurcations to Periodic Solutions in Diode Lasers Subject to Injection

For a diode laser with external optical injection, we derive a third- order differential equation for the phase of the field using asymptotic arguments. The bifurcations and isolated branches of time-periodic solutions we find, are compared with numerical results and experiments.

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MS37
Controlling Temporal and Spatio-Temporal Dynamics in Semiconductor Lasers by Delayed Optical Feedback

Delayed optical feedback may cause (spatio-) temporal instabilities, but also allows a succesful control of coherent regimes as well as stabilization of periodic and quasi-periodic regimes in otherwise temporally and/or spatially chaotic semiconductor lasers.

Christian Simmendinger and Ortwin Hess
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MS37
Control of Optical Turbulence in High Brightness Semiconductor Lasers

In the contexxt of a complex Swift-Hohenberg equation we discuss a robust control strategy, combining spatially and spectrally filtered optical feedback, that simultaneously allows temporal and beam steering control of the emmitted light.

J.V. Moloney and David Hochheiser
Arizona Center for Mathematical Sciences
Department of Mathematics
University of Arizona
Tucson, AZ 85721

MS37
Bifurcation Analysis of a Phase-Amplitude Model

of an Injected Diode Laser

Relaxation oscillations in an optically injected laser can be studied by means of a phase-amplitude equations, which define a vector field on a half-cylinder. We use bifurcation theory to learn about its dynamics with an emphasis on possible multi-stable regimes.

Bernd Krauskopf, Daan Lenstra, Wim van der Graaf
Bernd Krauskopf
Dept. of Physics and Astronomy
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MS38
Synchronizing Hyperchaotic Volume-Preserving Map Circuits

Most plans for using chaotic signals for communication assume that the chaotic signal will be used in a similar manner to the way pseudo- random binary signals are already used. Many continuous dissipative chaotic systems have power spectra with strong features that make them poor candidates for noise generators. We show a simple 3-D volume- preserving map circuit that has a flat power spectrum and a near delta function autocorrelation. The circuit is based on a linear map, so it is easy to design both the circuit and synchronizing subsystems. A transformation technique is used to create a synchronizing response system, since no natural subsystem exists.

Thomas L. Carroll
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MS38
Synchronizing Hyperchaos for Communications

Recent work pioneered by Pecora and Carroll has considered the possibility of exploiting the phenomenon of chaos synchronization to achieve secure communication. But, theoretical and experimental models studied thus far have been limited to low dimensional systems with one positive Lyapunov exponent. Consequently, messages masked by such simple chaotic processes are shown to be easily extracted in some cases. In this contribution we investigate high dimensional implementation of the Pecora-Carroll synchronization paradigm. In particular, in regard to potential applications to communication, we address the question of whether by transmitting just one scalar signal one can achieve synchronism in chaotic systems with two or more positive Lyapunov exponents (hyperchaos). Using both numerical and analytical examples we argue that under very general conditions the answer to the above question is affirmative.

Mingzhou Ding
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MS38
On Generalized Synchronization

Conditions for the occurrence of generalized synchronization of unidirectionally coupled dynamical systems are given in terms of asymptotic stability. The relation between generalized synchronization, predictability, and equivalence of dynamical systems is discussed. The theoretical results are illustrated by analytical and numerical examples.

Ljupco Kocarev
Faculty of Electrical Engineering, St. Cyril and Methodius University
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MS38
Multiplexing Chaotic Signals using Synchronization

Chaotic systems typically generate broadband signals. To achieve synchronization between two chaotic systems, a wide communication channel is usually required. However in real-world communication systems, channel bandwidth is limited. In this talk, we discuss various methods to increase the channel capacity via simultaneous transmission of multiple chaotic signals through the channel. Exploiting the stability properties of chaotic attractors allows for multiplexing chaotic signals either in frequency/time domain or directly in the state space without destroying chaotic synchronization. We demonstrate the principal possibility of multiplexing chaotic signals using synchronization both for iterated maps and ordinary differential equations.

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N.F.Rulkov, M.M.Sushchik, H.D.I.Abarbanel
Institute for Nonlinear Sciences, University of California
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MS39
Transition from Slow Motion to Pinning in Lattice Equations

Certain lattice differential equations from materials science exhibit slow motion of phase boundaries across many lattice sites when the ratio of intersite distance to interaction length is sufficiently small but undergo pinning of those transition layers when this ratio is increased. Analysis of the equilibria of these equations shows that the way in which this transition takes place may be surprisingly complex. We will present both analytical and numerical results.

Christopher P. Grant
Brigham Young University, Provo, UT

MS39
Modeling Biological Systems by means of Nonlinear Electronic Circuits

We present some results obtained in the framework of reaction-diffusion systems that may be usefull for understanding processes taking place in biological systems. In particular three mechanisms will be described: **i)** 1D model of the cardiac pulse propagation [?], **ii)** synchronization waves in 1D and 2D arrays of driven chaotic cells [?, ?] (related to propagation of information in nerve cells) and **iii)** description of 1D systems that exhibit periodic or chaotic behavior depending on an external perturbation (phenomenon similar to that observed during epileptic episodes) [?]. All the results here presented were obtained using as a basic cell a Chua's circuit that has been shown to exhibit a great variety of bifurcation and chaotic phe-

nomena [?].

A.P. Muñuzuri and L.O. Chua
Department of EECS,
University of Berkeley, USA

MS39
Traveling Waves in Lattice Dynamical Systems

The talk will discuss the existence, stability, and structure of traveling wave solutions in lattice dynamical systems, in particular, in coupled map lattices and lattice ordinary differential equations. The transition from standing waves to traveling waves will also be considered.

Wenxian Shen
Auburn University, Auburn, AL

MS39
Information Propagation, Pattern Formation and Reaction-Diffusion with Cellular Neural Networks.

Cellular Neural Networks are arrays of simple nonlinear dynamical systems in which each cell is connected to its nearest neighbors only. The local range of the connections is needed for their hardware implementation as analog circuits. Their applications mainly lie in image preprocessing tasks, for which it is essential to understand how the information (image), introduced as initial condition, propagates in the network: either by local diffusion between neighboring cells only, or global propagation through the entire array. We will study the dynamics of the network operating in both modes, and in particular we will look for the type and the number of stable steady state solutions, using exact mathematical methods whenever we can, or else approximate and numerical engineering approaches. We will also present some examples of biological pattern formation similar to the ones obtained with reaction-diffusion PDEs, and show how the coupling between cells is computed to create such patterns.

Patrick Thiran
Swiss Federal Institute of Technology at Lausanne
Switzerland
Gianluca Setti
University of Bologna
Italy

MS39
Traveling Waves, Equilibria, and the Computation of Spatial Entropy for Spatially Discrete Reaction Diffusion Equations

In this talk recent work on the dynamics of lattice differential equations, $\dot{u} = -f(u)$, arranged on the sites of a spatial lattice, is surveyed. In particular, results on propagation failure and lattice induced anisotropy for traveling wave or plane wave solutions in higher space dimensions spatially discrete bistable reaction-diffusion systems are considered. In addition, analysis of and spatial chaos in the equilibrium states of spatially discrete reaction-diffusion systems are discussed. We study stable equilibria for such systems, from the point of view of pattern formation and spatial chaos, where these terms mean that the spatial entropy of the set of stable equilibria is zero, respectively, positive. In particular, for an idealized class of nonlinearities f corresponding to a "double obstacle" at $u = \pm 1$ with $f(u) = \gamma u$ in between, it is natural to consider "mosaic solutions," namely equilibria which assume only the values $u_{i,j} \in \{-1, 0, 1\}$ at each $(i,j) \in \mathbb{Z}^2$. This in turn leads to explicit combinatorial criteria for the existence and stability of these equilibria. Rigorous upper and lower bounds on the spatial entropy of such stable mosaic solutions are obtained for a wide range of the coupling coefficients. In addition, a numerical method for estimating the spatial entropy is proposed and numerical results are presented.

John W. Cahn
NIST, Gaithersburg, MD

Shui-Nee Chow
Georgia Institute of Technology, Atlanta, GA

John Mallet-Paret
Brown University, Providence, RI

Erik S. Van Vleck
Colorado School of Mines, Golden, CO

MS40
From High Dimensional Chaos to Stable Periodic Orbits: the Structure of Parameter Space

Regions in the parameter space of chaotic systems that correspond to stable behavior are often referred to as windows. We elucidate the occurrence of such regions in higher dimensional chaotic systems. We describe the fundamental structure of these windows, and also indicate under what circumstances one can expect to find them. These results are applicable to systems that exhibit several positive Lyapunov exponents, and are of importance to both the theoretical and the experimental understanding of dynamical systems.

Ernest Barreto
Brian R. Hunt
Celso Grebogi
James A. Yorke
University of Maryland, College Park, MD

MS40
Optimal Periodic Orbits of Chaotic Systems: Control and bifurcations

Invariant sets embedded in a chaotic attractor can generate time averages that differ from the average generated by typical orbits on the attractor. Motivated by two different topics (namely, controlling chaos and riddled basins of attraction), we consider the question of which invariant set yields the largest (optimal) value of an average of a given smooth function of the system state. We present numerical evidence and analysis which indicate that the optimal average is typically achieved by a low period unstable periodic orbit embedded in the chaotic attractor.

Brian R. Hunt
Edward Ott
University of Maryland, College Park, MD

MS40
Periodic Shadowing

Shadowing techniques will be used to establish the existence of true periodic orbits near numerically computed pseudo periodic orbits in chaotic dynamical systems. The computational techniques will be illustrated to exhibit long

unstable periodic orbits in specific equations.

Huseyin Kocak
University of Miami, Coral Gables, Fl

MS40
Unstable Dimension Variability: A Source of Nonhyperbolicity in Chaotic Systems

The (non)hyperbolicity of a chaotic set has profound implications for the dynamics on the set. A familiar mechanism causing nonhyperbolicity is the tangency of the stable and unstable manifolds at points on the chaotic set. We investigate a different situation, first considered by Abraham and Smale in 1970, in which the dimensions of the unstable (and stable) tangent spaces are not constant over the chaotic set, thus causing nonhyperbolicity. A simple two-dimensional map that displays behavior typical of this phenomenon is presented and analyzed.

Eric J. Kostelich
Arizona State University, Tempe, AZ

Ittai Kan
George Mason University
C. Grebogi, E. Ott and J. A. Yorke,
University of Maryland, College Park, MD

MS41
Coriolis Forces as an SO(3) Gauge Field: Applications to Molecular Dynamics

Coriolis forces in the n-body problem are described by a non-Abelian SO(3) gauge field on the shape space of the system. This talk focuses on the new, geometrical perspective which this point of view brings to traditional problems in molecular dynamics. In the problem of small vibrations about an equilibrium, a natural choice of coordinates and gauge are Riemann normal coordinates and Poincare gauge, which turn out to be identical with the traditional Eckart conventions. Other problems, such as the Watsonian term in the quantum Hamiltonian, dynamics near collinear configurations, Yang-Mills field equations for the Coriolis field, and the 4-body kinetic energy operator, will be discussed.

Robert G. Littlejohn
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MS41
Geometric Phases and the Stabilization of Balance Systems

We discuss stabilization of mechanical systems with symmetry (rigid body with an internal rotor, the inverted pendulum and underwater vehicles). Starting from a Lagrangian with an unstable relative equilibrium, we introduce a modified Lagrangian whose Euler-Lagrange equations differ from the given ones by terms that can be identified with control forces. Equilibria of the modified Lagrangian are then analyzed using the energy-momentum method. When the method is used for tracking, it is necessary to take the geometric phase into account.

Jerrold E. Marsden
Caltech, Pasadena, CA

Anthony Bloch
University of Michigan, Ann Arbor, MI

Gloria Sanchez
University of Merida, Venezuela

Naomi Leonard
Princeton University, Princeton, NJ

MS41
The Phase for the Spatial Three-body Problem The three-body problem concerns a dynamical system whose configuration space is the space of triangles. If the triangle formed at time T is similar to the triangle at time 0, what is the rigid rotation which takes one triangle to the other,up to scale? The answer is well-known for the planar problem. We derive the answer for the spatial problem and fit it into the current Berry phase formalism.

Richard Montgomery
UC Santa Cruz, Santa Cruz, CA

MS41
Vortex Dynamics and the Geometric Phase

We will focus on applications of the Hannay-Berry (H-B) phase to vortex dynamics problems in 2-D incompressible ideal fluid flows. These flows include the three vortex problem, a vortex and particle in a circular domain, and a point vortex model for shear layer roll-up and pairing. Asymptotic methods which can be used to derive long time stretching rates for passive interfaces in these and other flowfields will be described and related to the geometric phase.

Paul K. Newton
University of Southern California, Los Angeles, CA

MS42
DNA Sequence Matching and Nonequilibrium Dynamics with Multiplicative Noise

Alignment algorithms used to search distant homologies among DNA (and protein) sequences are shown to belong to the same universality class as diffusive processes with correlated multiplicative noise. Analysis based on the dynamics analogy enables one to relate optimal choices of penalty parameters to the underlying evolutionary process responsible for sequence divergence. The popular "local" alignment method of Smith and Waterman can be cast in the same formalism, by introducing a constant source to the diffusive process.

Terence Hwa and Miguel A. Munoz
Physics Department
University of California at San Diego
La Jolla, CA

Dirk Drasdo and Michael Lassig
Max-Planck Institute
Teltow, Germany

MS42
RNA Virus Evolution: Fluctuation-Driven Motion on a Smooth Landscape

Recent experiments on the evolution of RNA viruses have shown several interesting dynamical features, all of which can be simply interpreted as being due to the process tak-

ing place on a smooth fitness landscape. Population dynamics on such a landscape are surprising; independent of the population size, one cannot use mean-field theory (the Eigen-Schuster equations) since the leading edge of the population (the most fit variants) always come in small numbers. We present here an exact asymptotic (in time) solution of a simple model of such a process and compare these results to simpler heurisitic methods.

Herbert Levine, Lev Tsimring and Douglas Ridgway
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La Jolla, CA 92093

David Kessler
Dept. of Physics
Bar-Ilan Univ.
Ramat-Gan, Israel

MS42
Why Do Proteins Look Like Proteins?

Protein structures in nature often exhibit a high degree of regularity (secondary structures, tertiary symmetries, etc.) absent in random compact conformations. We demonstrate in a simple lattice model of protein folding that structural regularities are related to high designability, evolutionary stability, and thermodynamic stability.

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Robert Helling
University of Hamburg
Hamburg, Germany

MS42
Dynamics of Flocking: How Birds Fly Together

We propose a non-equilibrium continuum dynamical model for the collective motion of large groups of biological organisms (e.g., flocks of birds, slime molds, etc.) Our model becomes highly non-trivial, and different from the equilibrium model, for dimension $d < d_c = 4$; nonetheless, we are able to determine its scaling exponents *exactly* in $d = 2$, and show that, unlike equilibrium systems, our model exhibits a broken continuous symmetry even in $d = 2$.

Yuhai Tu
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John Toner
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MS43
Quantum Interference in Microstructures: Signatures of Chaos

The nature of the classical dynamics of electrons in a microstructure can have a large effect on its quantum properties: in two examples we use semiclassical techniques to show that regular dynamics gives qualitatively different results from chaotic dynamics. First, the shape of the low-field magnetoresistance differs because of the long-time dynamics, an effect observed experimentally. Second, the magnetic susceptibility of interacting electrons is sensitive to families of periodic orbits. This short-path property of a regular system results in a parametrically larger susceptibility than for a chaotic system.

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MS43
Chaotic Dynamics and Quantum Level Statistics

Gutzwiller's trace formula relates quantum energy levels to classical periodic orbits. It can therefore be used to describe the correlations between quantum levels in terms of the statistical properties of the classical dynamics in a given system. The talk will be a review of some aspects of this theory, and the links with the corresponding correlations between the zeros of the Riemann zeta function.

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MS43
Experimental Studies of Quantum Chaos in Semiconductor Microstructures

The experimental aspects of mesoscopic physics will be discussed, including some details of fabricated and measurement at low temperature, as well as the strenghts and limitations of this experimental system. Recent measurements of electron transport through both open and classically isolated chaotic quantum dots will be compared to semiclassical and random matrix theory results.

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MS44
Lyapunov Spectra of Various Model Systems in Nonequilibrium Steady States

We discuss our recent numerical results for the Lyapunov spectra of the driven Lorentz gas, and for perturbed hard-disk and hard-sphere systems in two and three dimensions, respectively. To achieve a steady state various computer thermostats and time-reversible motion equations are used. Both mechanical (color conductivity) and thermal (shear viscosity) perturbations are considered. The ergodicity and macroscopic irreversibility of these systems are discussed.

Harald A. Posch
University of Vienna, Vienna, Austria

Christoph Dellago
University of Vienna, Vienna, Austria

MS44

Transport and Entropy Production in Low-Dimensional Chaotic Systems

We invoke concepts from the theory of dynamical systems to discuss the production of thermodynamic entropy from a microscopic point of view. For closed systems subjected to an external field, the necessity for thermostating leads to the well-known result that the entropy production is given by the sum of all averaged Lyapunov exponents governing the chaotic motion. When opening the system to allow for coupling to a particle reservoir, one has to deal with open systems exhibiting transient chaos. In this case the concept of the conditional probability density is used to define an entropy. The production of entropy turns out to be proportional to the difference of the escape rate from the open system and the sum of all averaged Lyapunov exponents on the chaotic saddle governing the dynamics. The relation between the closed and open system approach will be illustrated by the example of a multibaker map.

Tamas Tel
W. Breymann and J. Vollmer
Eotvos University, Budapest, Hungary

MS44

Lyapunov Exponents and Irreversible Entropy Production in Low Density Many-Particle Systems

For dilute many-particle systems kinetic theory methods can be used to calculate characteristic dynamical properties, such as Lyapunov exponents and Kolmogorov-Sinai entropies. The change in these quantities when the system is brought out of equilibrium into a stationary or quasi-stationary state can be related to transport properties (e.g. diffusion coefficients) of the system. Especially, for a system subjected to a constant driving field and a Gaussian thermostat keeping the kinetic energy constant, the sum of all Lyapunov exponents is directly proportional to the macroscopic irreversible entropy production. A correct identification requires a coarse-graining of the phase space density as it keeps concentrating on a fractal attractor. Similarly, for systems with open boundaries one finds a positive irreversible entropy production related to coarse graining of the phase space density on the fractal repeller, i.e. the set of trajectories that remain trapped within the system forever.

Henk van Beijeren
Universiteit Utrecht
Utrecht, The Netherlands

J. Robert Dorfman
University of Maryland
College Park, MD

MS45

Two Coupled Lasers

Steady and oscillatory forms of synchronization of two coupled lasers are analyzed in detail. The mathematical problem is motivated by recent experiments on coupled solid state lasers and coupled semiconductor lasers. We investigate the bifurcation diagram of the steady and periodic states analytically and numerically. We control the strength of the mutual coupling, the pump level of the individual lasers, and the frequency detuning between them.

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MS45

Entrainment of Coupled Solid State Lasers

A discussion of the dynamics and control of coupled solid state lasers with an injected field will be presented. This will focus on the basic equations and entrainment mechanism, and the use of phase models to describe the dynamics in certain regimes. Predictions, including the strongly non-monotonic dependence of the output power on the drive amplitude below the entrainment threshold, and the suppression of amplitude instabilities by the injected field, will be discussed.

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MS45

Design of Laser Resonators for Enhanced Spatial Coherence and Mode Control

Most laser resonators employ conventional lenses and mirrors to establish a fundamental laser mode. We explore the larger design space made available by utilizing diffractive optical elements as end mirrors and intracavity elements with complex reflectivities. Coherence is established across semiconductor laser arrays by designing external cavity resonators that establish a common array mode. Mode control of high Fresnel number solid-state lasers is enhanced by intra-cavity phase plates. The mathematical techniques used to design laser resonators for specific mode shapes and optimum modal discrimination are reviewed.

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MS45

Nonlinear Dynamics of Semiconductor Laser Arrays

Semiconductor laser arrays are of great interest as high power coherent sources. They are also of fundamental interest because they exhibit complex spatiotemporal dynamics that can be understood in terms of simple coupled-mode theories or more general partial differential equation models. We review the theoretical approaches to laser ar-

ray dynamics and present a survey of relevant experimental results.

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MS46
On Oscillations of Solutions of Randomly Forced-Damped NLS Equations

We consider the small-dispersion and small-diffusion nonlinear Schrödinger equation

$$-i\,\dot{u} = -\delta_1 \Delta u - i\delta_2 \Delta u + |u|^2 u + \zeta_\omega(t,x), \quad 1 \geq \delta := \sqrt{\delta_1^2 + \delta_2^2} > 0,$$

where the space-variable x belongs to the unit n-cube ($n \leq 3$) and u satisfies Dirichlet boundary conditions. Assuming that the force ζ is a zero-meanvalue random field, smooth in x and stationary in t with decaying correlations, we prove that the C^m-norms in x with $m \geq 3$ of solutions u, averaged in ensemble and locally averaged in time, are larger than $\delta^{-\kappa m}$, $\kappa \approx 1/5$. This means that the length-scale of a solution u decays with δ as its positive degree (at least, as δ^κ) and – in a sense – proves existence of turbulence for this equation.

Sergei B. Kuksin
Steklov Mathematical Institute, Moscow

MS46
Self-Focusing of the Nonlinear Schrödinger Equation and itsBbehavior Under Small Perturbation

The nonlinear Schrödinger equation has complicated self-focusing behavior in the critical case (cubic nonlinearity and two space dimensions) and the modification of this behavior when external perturbations are present is of great interest in many applications. We will examine in detail the mathematical problems that arise and present some applications, such as the effect of small time dispersion. This is joint work with Gadi Fibich.

George Papanicolaou
Department of Mathematics
Stanford University

MS46
Invariant Manifolds for a Class of Dispersive, Hamiltonian, Partial Differential Equations

We construct an invariant manifold of periodic orbits for a class of nonlinear Schrödinger equations. Using standard ideas of the theory of center manifolds, we rederive the results of Soffer and Weinstein on the large-time asymptotics of small solutions (scattering theory).

Claude-Alain Pillet
Département de Physique Théorique
Université de Genève Geneva, Switzerland

Clarence Eugene Wayne
Department of Mathematics
The Pennsylvania State University
University Park, PA

MS46
Resonances and Radiation Damping in Conservative Nonlinear Waves Consider a linear wave or Schrödinger equation which supports (stable) time-periodic and spatially localized solutions (bound states). This talk concerns recent work on the character of such bound states under nonlinear and conservative perturbations in the dynamics. Some bound states may not persist under perturbations and may decay due to nonlinear resonant interactions with radiation modes. Such states may decay very slowly as $t \to \infty$ and are therefore *metastable states.* A system is studied in which the excited states decay and a ground state is selected by the evolution. This is joint work with Avy Soffer.

Michael I. Weinstein
Department of Mathematics
University of Michigan, Ann Arbor

MS47
Targeting in Soft Chaotic Hamiltonian Systems

The problem of directing a trajectory of a chaotic dynamical system to a target has been previously considered, and it has been shown that chaos allows targeting using only small controls. In this paper we consider targeting in a Hamiltonian system which has a mixed phase space consisting of chaotic regions and KAM surfaces. The orbit can be guided through regions of strong chaos relatively quickly. Controlled motion through KAM regions may be much slower. We discuss targeting strategies under these circumstances.

Christian G. Schroer and Edward Ott
University of Maryland
College Park, MD

MS47
Controllable Targets for use with Chaotic Controllers

A nonlinear system with a chaotic attractor produces random like motion on the attractor. This observation leads to a very simple "Chaotic control" algorithm for bringing nonlinear systems to a fixed point contained within a "controllable target". A novel approach for determining controllable targets for discrete systems is presented. Two discrete control problems are examined. The first example is the well known Hénon map and the second example is the bouncing ball. The method is also shown to be applicable to controlling a continuous double link pendulum system. A video of the ball system and the double pendulum system under control will be shown.

Thomas L. Vincent
University of Arizona
Tucson Arizona 85721

MS47
Limits to Deterministic Modeling

Some systems have an attractor with two periodic orbits having different numbers of unstable directions. Such orbits typically do not have the shadowing property so numerical orbits do not represent true orbits. The talk is based on joint work with Leon Poon, Celso Grebogi, and

Tim Sauer.

James A. Yorke
I.P.S.T.
University of Maryland
College Park, MD 20742-2431

MS47
A Chaotically Forced Pendulum: Ship Cranes at Sea

We present a control strategy for mitigating the pendulation of the crane load during open sea transfer operations. This is realized by adding a pulley-brake system to the current crane configurations. Numerical simulations show that the braking is very effective in controlling load pendulations induced by representative ship roll motions. Furthermore, the amount of braking is a desirable control variable for various control algorithms.

Guohui Yuan, Brian Hunt, Celso Grebogi, Edward Ott, James Yorke
University of Maryland
College Park, MD

Eric Kostelich
Arizona State University
Tempe, AZ

MS48
A Beteroclinic Network with Noise

In a 1994 paper, we described a heteroclinic network in which delicate types of attracting behaviour could be seen. For example, it was shown that two cycles in the network could attract significant sets of initial conditions without either cycle being asymptotically stable or essentially asymptotically stable. This talk describes recent work on the effect of additive noise on the attractivity properties of the heteroclinic network.

Vivien Kirk
The University of Auckland, Auckland, New Zealand

Mary Silber
Northwestern University, Evanston, IL

MS48
Probability Densities for Qualitatively Modified Dynamics

The effect of small noise in systems with slow-fast dynamics can be quite dramatic. For example, chaotic behavior of the deterministic system is replaced by noisily periodic behavior, and delay and memory effects can be eliminated. A new global description of these dynamics can be given in terms of the probability density function. We give both analytical approximations and numerical solutions for these probability densities in several areas of application, including resonant interactions, nerve membrane excitability, and laser dynamics.

Rachel Kuske
Tufts University, Medford, MA 02155

George Papanicolaou
Department of Mathematics, Stanford University, CA

Steve Baer
Department of Mathematics, Arizona State University, Tempe, AZ

MS48
Noise-Controlled Dynamics in Normal Forms

Additive noise of very small amplitude qualitatively changes the behaviour found in truncated codimension-2 normal form equations. Here we analyse the equations describing the interaction of a Hopf bifurcation with another simple bifurcation. The effect of the noise is to postpone a global (heteroclinic) bifurcation; instead of going to infinity, trajectories follow noisily periodic orbits with well-defined mean amplitude and distribution about the mean.

Grant Lythe
Center for Nonlinear Studies, MS-B258 Los Alamos National Laboratory, NM

Steve Tobias
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MS48
Noisy Cycles, the Sequel

In an earlier paper (Stone and Holmes 1990) we reported on the effect of small amplitude noise on the cycle time of a trajectory near an attracting hetero/homoclinic orbit. In this talk I will generalize these results to systems to with heteroclinic connections between more complicated limit sets, such as limit cycles or chaotic limit sets. Ways to implement these results in an experimental setting will be discussed.

Emily F. Stone
Utah State University, Logan, UT

Dieter Armbruster
Arizona State University, Tempe, AZ

MS49
Smale
Horseshoes in Perturbed Nonlinear Schroedinger Equations

The existence of Smale horseshoes and symbolic dynamics is established in the neighborhood of a symmetric pair of homoclinic orbits in the perturbed NLS equation. More specifically, a list of compact invariant Cantor sets are constructed through a study on the Conley-Moser conditions. The Poincare map restricted to each of the Cantor sets, is topologically conjugate to the shift automorphism on four symbols. This gives rise to deterministic *chaos* which offers an interpretation of the numerical observation on the perturbed NLS equation: The chaotic center-wing jumping.

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MS49
The Fate of Traveling Waves of the Nonlinear Schrödinger equation under Ginzburg-Landau Type Perturbations

The nonlinear Schrödinger (NLS) equation is a famous integrable pde with many traveling wave solutions. The com-

plex Ginzburg-Landau (CGL) equation can be viewed as a dissipatively perturbed NLS equation, and is a generic envelope equation derived in many applications. I will give a nearly complete account of what happens to all the periodic and solitary traveling waves of NLS type equations when they are perturbed with CGL type perturbations.

C. David Levermore, Gustavo Cruz-Pacheco
and Ben Luce
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Los Alamos, NM 87545

MS49
Homoclinic Orbits in the Maxwell-Bloch Equations of Nonlinear Laser Optics

This talk will describe some of the spatio-temporal dynamics of a pumped ring-cavity laser, which is modeled by the Maxwell-Bloch partial differential equations with spatially periodic boundary conditions. Numerical simulations of this spatially dependent system show both regular and chaotic behavior of the solutions, depending on the values of the parameters, which are the cavity length, pumping strength, material relaxation rates, and cavity losses. The stable regular structures which have been observed in the simulations include traveling waves and stable spatially independent solutions. The chaotic dynamics are manifested as unidirectional waves whose speed and height vary in a seemingly random fashion, but whose other features, such as the number of "crests" per spatial period remain constant in time, indicating the low-dimensional nature of the process. Spatially-dependent orbits homoclinic to an unstable saddle-focus are proven to exist by a combination of the "dressing" method from the inverse-scattering theory and the homoclinic Melnikov method. These orbits provide a posible mechanism for the chaotic dynamics.

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Thomas A. Wettergren
Naval Undersea Warfare Center
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MS49
The Nonlinear Schrödinger Equation: Asymmetric Perturbations, Traveling Waves and Chaotic Structures

Hamiltonian perturbations of the nonlinear Schrödinger equation (NLS) can produce a novel type of chaotic evolution. The chaotic solution is characterized by random bifurcations across standing wave states into left and right going traveling waves. In this class of problems where the solutions are not subject to even constraints, the traditional mechanism of crossings of the unperturbed homoclinic manifolds is not observed. I will present an analytical description of chaos in Hamiltonian perturbations of the NLS that will include this new phenomena of chaotic traveling waves.

Constance Schober
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MS50
Standing Waves, Heteroclinic Connections, and Parity Breaking in Bifurcations from Ordered States of Cellular Flames

Cellular flames form ordered patterns of concentric rings which bifurcate to dynamical states. Three examples of dynamical states will be discussed: rotating states exhibiting asymmetric cells characteristic of parity-breaking bifurcations; standing-wave states corresponding to an oscillation of an N-fold pattern which rotates by $2\pi/N$ on each half cycle; and intermittently ordered states in which a pattern of cells appears and disappears at irregular intervals corresponding to a network of heteroclinic connections among unstable equilibria.

Michael Gorman
University of Houston
Houston, TX

Kay Robbins
University of Texas at San Antonio
San Antonio, TX

MS50
Spatiotemporal Pattern Formation in Combustion

In recent experiments with high Lewis number flames propagating in a tube, Pearlman (cf. this minisymposium) observed flames exhibiting pacemaker target patterns, spirals and other interesting spatiotemporal patterns. In this talk we will pose a simple model of flames, and exhibit solutions which describe these flames, well as other, as yet unobserved flames.

Alvin Bayliss
Northwestern University, Evanston, IL

Bernard J. Matkowsky
Northwestern University, Evanston, IL

MS50
Excitability in Premixed Gas Combustion

Target and spiral waves patterns have been observed in freely-propagating and burner-stabilized premixed gas flames when the mixture Lewis number (ratio of mixture thermal diffusivity to mass diffusivity of the deficient component) is larger than one. The occurrence of such patterns appears to be extremely sensitive to the mixture composition as well as local heat loss. Experimental measurements of the temperature and composition profiles as well as flame-induced hydrodynamic flow will be presented along with details of the flame dynamics as a function of parameter space.

Howard Pearlman
NASA Lewis Research Center
Cleveland, OH

MS50
Nonlinear Dynamics in Combustion Synthesis of Materials

In this talk we describe a variety of nonlinear dynamical modes of propagation of combustion synthesis waves. We discuss both experimental observations and theoretical studies, as well as comparisons between them.

Vladimir A. Volpert

Northwestern University, Evanston, IL

MS51
Blowout-Type Bifurcations in Symmetric Systems

Basin riddling and other associated phenomena of blowout bifurcation occur naturally in systems with symmetry; this is due to the invariant subspace structure forced by the symmetry. I will discuss some connections between this and related phenomena such as structurally stable heteroclinic cycles.

Peter Ashwin
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MS51
Synchronized Chaos, Intermingled Basins and on-off Intermittency in Coupled Dynamical Systems

Recent work has shown that chaotic systems possessing certain symmetries can exhibit a novel class of phenomena including riddled basins, intermingled basins and on-off intermittency. In this talk, we first show that intermingled basins can be easily realized in the context of coupled oscillators exhibiting synchronized chaos. This opens the possibility of investigating these phenomena in laboratory experiments. Then, we derive explicit conditions for the stability of synchronized chaos in globally coupled map lattices where the individual map can be arbitrary dimensional. We further show that after the synchronized chaos loses stability one generally observes on-off intermittency.

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MS51
Riddling Bifurcation in Chaotic Dynamical Systems

When a chaotic attractor lies in an invariant subspace, as in systems with symmetry, riddling can occur. Riddling refers to the situation where the basin of a chaotic attractor is riddled with holes that belong to the basin of another attractor. We establish properties of the riddling bifurcation that occurs when an unstable periodic orbit embedded in the chaotic attractor, usually of low period, becomes transversely unstable. An immediate physical consequence of the riddling bifurcation is that an extraordinarily low fraction of the trajectories in the invariant subspace diverge when there is a symmetry-breaking.

Celso Grebogi
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MS51
Characterization of Blowout Bifurcation by Unstable Periodic Orbits

Blowout bifurcation in chaotic dynamical systems occurs when a chaotic attractor, lying in some invariant subspace, becomes transversely unstable. We establish quantitative characterization of the blowout bifurcation by unstable periodic orbits embedded in the chaotic attractor. We argue that the bifurcation is mediated by changes in the transverse stability of *an infinite number of unstable periodic orbits*. There are two distinct groups of periodic orbits: one transversely stable and another transversely unstable. The bifurcation occurs when some properly weighted transverse eigenvalues of these two groups are balanced.

Ying-Cheng Lai
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PS01
A Hydrodynamic Theory of Mass Transport

We present here a two dimensional mathematical picture that describes the motion of dust particles in a continuous fluid such as water. In our description of hydrodynamic forces on the particles we show how the Lagrangian formalism can be used to find a general expression for these forces. This model can serve as an initial step toward formulating the hydrodynamics of sediment transport. This is an important problem in the field of oceanography and other disciplines as well.

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PS01
Dynamical Features Simulated by Recurrent Neural Networks

The evolution of simple two dimensional recurrent neural networks with saturated linear or sigmoidal transfer functions presents a whole spectrum of dynamical behaviors, ranging from highly predictable dynamics, where almost every orbit accumulates to an attracting fixed point, to the existence of chaotic regions with cycles of arbitrarily large period. Moreover, recurrent analog neural networks with rank one connecting matrices are good approximators of compact supported real-valued continuous maps under a convenient choice of encoding and deconding procedures.

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PS01
Using Spatial Disorder to Synchronize Dynamical Systems

We study the effect of quenched disorder on the synchronization of dynamical systems. In particular, we study arrays of coupled Josephson Junctions, coupled Duffing oscillators, and coupled maps. We find that disorder can synchronize chaotic arrays of otherwise identical elements and thereby tame spatiotemporal chaos. We exhibit arrays that evolve chaotically when homogeneous but evolve periodically when heterogeneous. We find that there exists optimal amounts of disorder which minimize the leading Liapunov exponents of these arrays.

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PS01
Information Content of Cellular Automaton Traffic Simulations

Using a symbol dynamics approach, we develop a method for measuring the information content in cellular-automaton simulations of vehicular traffic. We present applications of the method to TRANSIMS (a TRansportation ANalysis and SIMulation System being developed for the U.S. Department of Transportation), showing how the Renyi entropy varies and scales as a function of sampling procedure and simulation parameters.

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PS01
Inertial Functions: Definition, Existence and Stability

We introduce a generalisation of the inertial manifold, which we call an inertial function. This is a function whose graph is invariant under the dynamics and is exponentially attracting for almost all initial conditions. The construction and smoothness of this inertial function is based on the Lyapunov exponents of the dynamical system and on properties of an absorbing set. We discuss conditions for the existence of such a function, along with its stability to deterministic perturbations and noise.

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PS01
Spectra of Frequency-Modulated Waves

The energy spectra of a sinusoid, frequency modulated by a stationary random process of various distributions, are investigated. Wide band noise as well as random noise filtered through Butterworth filters of even and odd order are considered. A general expression for the Butterworth filter case is provided The closed form solutions take the form of complementary error functions of complex arguments and are compared to classical solutions obtained using statistical communication theory.

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PS01
Enhancing Stochastic Resonance in a Single Unit

We show that the stochastic resonance (SR) effect in a single nonlinear unit can be enhanced by modulating the input noise intensity with either the input signal or the unit's output rate signal. We demonstrate that SR enhancement will occur even if the noise modulation is time-delayed with respect to the signal. We analyze SR enhancement theoretically for generic nonlinear systems and demonstrate it numerically in the FitzHugh-Nagumo model.

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PS01
Control of Uncertain Mechanical Systems Using Reduction and Adaptation

This paper considers the motion control problem for a broad class of uncertain mechanical systems; systems belonging to this class include holonomically constrained systems, nonholonomic systems, and systems for which the dynamics admits a symmetry. It is proposed that a simple and effective solution to this problem can be obtained by first using a reduction procedure to obtain a lower dimensional system which retains the mechanical system structure of the original system, and then adaptively controlling the reduced system in such a way that the complete system is driven to the goal configuration. This approach is shown to ensure accurate motion control even in the presence of considerable uncertainty concerning the system model and state. The efficacy of the proposed control strategy is illustrated through extensive computer simulations and hardware experiments.

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PS01
The Magnetic Pendulum

In this work we study the dynamical behavior of a ferromagnetic pendulum, which is subject to gravitational, magnetic and frictional forces. The magnetic force is pro-

duced by three strong magnet, which are attractor or repulsor points positioned a short distance below the pendulum plane at the vertices of any triangle. The friction force depends on the velocity.

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PS01
Symmetry-Breaking Parametric Instabilities in Circular Josephson Junction Arrays

We use equivariant bifurcation theory to investigate parametric instabilities of the in-phase periodic state of a circular array of Josephson junctions. Watanabe, et al. showed that these instabilities are associated with steps in the I-V curve of the array. Our analysis extends their linear results to the weakly nonlinear regime. We determine existence and stability of the period-doubled solution branches as a function of various physical parameters in the governing equations.

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PS01
Numerical Evidence of Standing and Breathing Solutions for the Oregonator with Equal Diffusivities

We consider a simple model of the Belousov-Zhabotinskii reaction a gel reactor coupled to a reservoir. Using the Oregonator reaction kinetics in the reactor we give numerical evidence of stable (or Meta-stable) large amplitude standing patterns in the case that all of the diffusivities are equal. We also give numerical evidence that these patterns destabilize as one varies the domain size via a Hopf bifurcation giving rise to Breather solutions.

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PS01
Modelling and Phase Analysis of Immunological Process at Primary Immune Response

A mathematical model of a specific immunological process for venous immunization of rabbits by the haemorrhagic disease virus is developed. On the basis of the qualitative theory of ordinary differential equations a phase analysis of this immunological process is carried out in the kinetic variables plane - antigens concentration and antibodies concentration. The phase portait of the discussed nonlinear model in two-dimensional domain is constructed. The mutual relationship between the antigens reproduction rate and phase portrait is investigated in a qualitative way.

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PS01
Newton-Picard Methods for Robust Continuation and Bifurcation Analysis of Periodic Solutions of Infinite-Dimensional Dynamical Systems with Low-Dimensional Dynamics

Newton-Picard methods combine direct solvers and Picard iteration schemes to solve the linearised systems that arise in the shooting method and provide good estimates for the dominant Floquet multipliers during this process. In this poster, we will show how this information can be used to make continuation more robust and to detect bifurcation points. We will also show how to apply the Newton-Picard method to extended systems to accurately compute these bifurcation points.

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PS01
Continuum Limits of Convective-Diffusive Lattice Boltzmann Methods

The connection between a diffusive lattice gas and the corresponding macroscopic convective-diffusive equation is described. Lattice Boltzmann methods are numerical schemes derived as a kinetic approximation of an underlying lattice gas. The continuum limit of a lattice Boltzmann method is formally shown to converge to the macroscopic equation. The result is based on a formal derivation in which limitting moments are balanced rather than on a classical expansion.

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PS01
Reconstruction and Prediction of Stochastic Dynamical Systems using Topology Preserving Networks

Starting with a scalar time series, we present the use of Topology Preserving Networks, as for example the Kohonen Network and the Neural Gas Algorithm, to define a Voronoi partition and its dual, the Delaunay Triangulation. The partition is then used, to compute the transition probabilities defining the Markov chain of the system. This probability set can then be used to predict the time series, and to reconstruct the flow and the attractor of the system. The method can be used for deterministic, as well as chaotic and stochastic dynamical systems.

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PS01

Complex Dynamics of Coupled Quantum Wells with Local Mean Field Interaction; Bifurcations of Periodic Orbits in a Hamiltonian System with Symmetry

We analyze a discrete semiclassical model of coupled quantum wells with short-range mean-field interaction in one site. The system evolves according to the time dependent Schrödinger equation with a nonlinear electrostatic term. The simplest vector field that accounts for the complex dynamical behavior present in the continuum case turns out to be eight dimensional and can be written conveniently with $\mathbb{C}^4$ variables in a hamiltonian formalism. The system is invariant under rotations in $\mathbb{C}^4$, reversible ($H(z,\overline{z}) = H(\overline{z}, z)$) and autonomous. The conserved quantities are the energy and the total charge. The organizing centers for the complex dynamical behavior are bifurcations of rotating periodic solutions. Its simple structure allows a thorough analytical investigation of the bifurcations as the conserved quantities are varied.

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PS01

Heteroclinic Networks in Coupled Cell Systems

We consider a system of n identical cells, with identical, all-to-all coupling. The system exhibits both internal (cell-wise) and global (permutational) symmetry. We show by construction that the system allows a heteroclinic network, which consists of a set of equilibria connected by a series of trajectories. We then show how this network leads to interesting intermittent behavior in the system, which has a natural interpretation in terms of coupled cells

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PS01

Control of Differentially Flat Robotic Systems In the Presence of Uncertainty

This paper considers the problem of controlling uncertain robotic systems which are *differentially flat*, that is, which admit a set of outputs with the property that there is a one to one correspondence between output curves and system trajectories. It is shown that a simple and effective solution to this problem can be obtained by combining a trajectory generation algorithm for the flat outputs with an adaptive tracking controller for a set of "reducing" outputs. The utility of this approach is illustrated through both computer simulations and hardware experiments with several important robotic systems, including a mobile robot, an underwater vehicle, a space robot, and a ducted fan.

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PS01

Effects of Anisotropy on Nonlinear Evolution of Morphological Instability in Directional Solidification

Effects of anisotropy of surface tension and kinetic coefficients on nonlinear evolution of morphological instability in the course of rapid directional solidification is studied. It is shown that, due to anisotropy, morphological instability generates deformational waves propagating in a preferred direction governed by anisotropy. Nonlinear evolution of these waves is governed by anisotropic dissipation-modified Korteweg de Vries equation and anisotropic Kawahara equation. Solutions of these equations in the form of cnoidal and solitary waves and their stability are studied.

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PS01

Application of Centre Manifold Theory to an Adaptive Control Problem

Certain partially known discrete-time nonlinear control systems are dealt with. The control objective is the asymptotic regulation of the output. To this purpose, an adaptive control scheme is implemented. The resulting closed loop is a discrete-time dynamical system with non-hyperbolic fixed points. By means of the Centre Manifold Theory, a result on the stabilization of the system about its fixed points is stated. From this, a local result on the firstly proposed control objective is obtained.

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PS01

Symmetry Breaking Perturbations and Strange Attractors

The asymmetrically forced, damped Duffing oscillator is introduced as a prototype model for analyzing the homoclinic tangle of symmetric dissipative systems with *symmetrybreaking* disturbances. Even a slight asymmetry in the perturbation may cause a substantial change in the asymptotic behavior of the system, e.g. transitions from two sided to one sided strange attractors. Numerical evidence indicates that *strangeattractors* appear near curves which are found analytically and correspond to specific secondary homoclinic bifurcations.

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PS01

Computing the Measure of Nonattracting Chaotic Sets

Recently, a numerical method, called the PIM-triple algorithm, has been formulated for generating long orbits on nonattracting chaotic sets. We investigate under which conditions the measure for a nonattracting invariant set

generated by the PIM-triple algorithm agrees with the natural measure.

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PS01

Scaling of Travelling Waves Produced from Electrostatic Instabilities

Recent studies of electrostatic instabilities in Vlasov plasma have shown that the amplitude equations have a non-trivial scaling behavior arising from singularities in the nonlinear coefficients. The analysis of the amplitude equations does not establish the time-asymptotic state of the instability, but other research suggests that these instabilities often result in the appearance of nonlinear travelling waves. In addition, rigorous investigations of the bifurcation of travelling waves (by Holloway and Dorning) prove the existence of solution branches, but do not establish any relation between the nonlinear travelling waves and the initial value problem. Thus the scaling of the waves with γ (the linear growth rate) near the onset of a linear instability is not determined. We consider a family of Vlasov equilibria $F_0(v,\gamma)$ that cross the threshold of linear stability at $\gamma = 0$ and formulate the equations for branches of travelling waves $F_{tw}(x,v,t,\gamma)$ that bifurcate from $F_0(v,0)$ and belong to the same symplectic leaves as $F_0(v,\gamma)$. The analysis of singularity structure of the equations provides information about the asymptotic scaling of $F_{tw}(x,v,t,\gamma)$ as $\gamma \to 0^+$.

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PS01

Bifurcations in Systems of Coupled Bistable Units

Systems of coupled bistable units have been employed to investigate phenomena such as phase-separation, multistability, propagation failure and neural dynamics. Here we show how to analytically determine the existence and stability properties of fixed points of piecewise-linear coupled map lattices, then use this technique to investigate the bifurcations undergone by systems of diffusively-coupled bistable maps. We show how the bifurcations lead to many interesting phenomena, such as the coexistence of travelling waves and localised stationary solutions.

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PS01

Numerical Analisys of Phase Synchronization of Coupled Model Neurons

We suggest the way of numerical analysis of collective behavior of coupled chaotic model neurons. The method is based on evaluation of "phase" of chaotic dynamical system according to the approach suggested by [Kurths, *et al.*, 1996]. Excited neuron is known to demonstrate two kinds of behavior: fast spiking and slow bursting. Action potential of such a neuron possesses two different time scales — the average period of a bursts and the average length of spikes. We calculate two phases of coupled neurons (more exact, the phase difference) and study their behavior for different values of coupling strength.

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PS01

Forced Symmetry–breaking in Coupled Oscillator Networks

We present a numerical and theoretical investigation into the effects of small symmetry–breaking terms on the bifurcations of a ring of nominally identical oscillators. The fully symmetric system has $\mathbf{D}_n$–symmetry and the theory of Hopf bifurcation with symmetry can be used to determine the types of oscillation possible. When symmetry–breaking terms are included, the behaviour near the Hopf bifurcations is significantly changed, leading to, for example, stabilisation of previously unstable patterns.

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PS01

Taking the Temperature of an Epileptic Seizure

A surprisingly accurate and easily computed indicator of the onset and duration of an epileptic seizure is obtained by interpreting the windowed re-embedded trajectory as a cloud of particles in phase space and monitoring the average kinetic energy of the particles in the cloud as a function of time.

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PS01

Global and Local in Time Solutions of Laplacian Growth Equation: Criteria for Cusps

A geometric (and group-theoretic) description of the configuration space for the Laplacian growth equation is presented. The differences between global in time solutions and local in time solutions are discussed. Global solutions are free of cusps. The local solutions necessarily develop cusps. The criteria that the initial data must satisfy in order that the solutions be free of cusps (global in time) are formulated.

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PS01

Using Linear Integro-Difference Equations to Emulate Solutions to a Temporally Stiff System of PDE's

We examine a system of evolution PDE's modelling the movement of Mountain Pine Beetles in western forests. Several problems are involved. The first is that the evolution of different variables takes place on different time scales. Moreover, a variety of spatial scales couple forest and beetle interaction. Multiple scale methods allow us to decouple the problem, creating an emulation strategy for the PDE solution in terms of iterations of an IDE. Whereas the system of PDE's is impossible to solve except through computationally lengthy numerical procedures, the IDE is relatively simple, saving several orders of magnitude of computational time.

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PS01

Dynamics in the Undergraduate Mathematics Program

The concepts of dynamics are introduced in two courses, Mathematical Modeling and Differential Equations with Linear Algebra, both having a prerequisite of Calculus II. Intermediate concepts are studied in Advanced Differential Equations. The opportunity to further develop these concepts is an option in Senior Project, the capstone course required of all math majors. It in turn is given in two parts: 1 cr in the Fall where the topic is chosen and outlined, and 2 cr in the Spring where it is developed in Hypercard or the Mathematica Notebook. Examples of projects will be illustrated.

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PS01

Forced Vibration of a Partially Delaminated Beam

The forced vibration of a partially delaminated structure such as an aircraft wing can result in catastrophic crack growth. A cantilever beam with a single delamination at its free end is considered. We examine, both numerically and analytically, the resulting motions from a mathematical model of the system subject to a harmonic forcing of the main beam. The model displays several types of motion; periodic, chattering-periodic and chaotic motion. Experimental evidence for some of these is provided.

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PS01

Two Meaningful Alternative Representations of Dynamic Behaviour

In teaching dynamics to undergraduates via time-dependent differential equations, the computer's use rests on the algorithm. However, we note that the strictly mathematical representation of dynamics (via differential/difference equations) is computationally implemented via algorithms which usually rigidly advance time uniformly and re-compute the same formula(-ae) recursively. Yet, strictly algorithmic models permit one to represent the dynamics of biological and/or social systems much more scientifically [AN EPISTLE TO DR. BENJAMIN FRANKLIN, Exposition-University Press, 1975(1974)].

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PS01

Integro-Differential Model for Orientational Distribution of F-Actin in Cells

We model angular self-organization of actin cytoskeleton as a process of instant changing of filament orientation in the course of peculiar actin-actin interactions. These interactions are modified by cross-linking actin-binding proteins. The mathematical model consists of a single Boltzmann-like integro-differential equation for the two-dimensional angular distribution. The linear stability analysis, asymptotic analysis and numerical results reveal that at certain parameters of actin-actin interactions spontaneous alignment of filaments in the form of unipolar or bipolar bundles or orthogonal networks can be expected.

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PS01

Synchronization of Structures by a Small Number of Couplings

The interactions of localized coherent structures formed in two almost identical but different chains of bistable elements both against unexcited and chaotic backgrounds are investigated. Numerical solutions are used for analysis of the features of mutual synchronization of such structures in the presence of localized couplings between them. The

transition to synchronization occurs through the synchronization "front" propagating from the point of coupling to the edges of the structures. The velocity of front propagation is plotted versus the difference in natural frequencies of the structures, δ. Qualitative description of the effect is proposed. It is shown that the coupled structures in synchronized and non-synchronized regimes differ, first of all, by the distribution of oscillatory phases of their elements. Possible use of this circumstance for experimental verification of the synchronization between this and some other structures is discussed for the situations when the characteristics of the latters cannot be measured to a sufficient extent.

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PS01
Hamiltonian Moment Reduction for Describing Vortices in Shear Flow

A general method for modeling long-lived quasigeostrophic vortices is given. The method is based upon the noncanonical Hamiltonian structure of the ideal fluid and uses moments of the vorticity as dynamical variables. The method provides a means of extracting, either exact or approximate finite degree-of-freedom Hamiltonian systems from the partial differential equations that describe quasigeostrophic vortex dynamics. The method is applied to the Kida problem and the dynamics of an ellipsoidal region of uniform potential vorticity.

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PS01
Controlling On-Off Intermittent Dynamics

On-off intermittent chaotic behavior occurs in physical systems with symmetry. The phenomenon refers to the situation where one or more physical variables exhibit two distinct states in their time evolution. One is the "off" state where the physical variables remain constant, and the other is the "on" state where the variables temporarily burst out of the "off" state. We demonstrate that by using arbitrarily small feedback control to an accessible parameter or state of the system, the "on" state can be eliminated completely. This could be practically advantageous where the desirable operational state of the system is the "off" state. Relevant issues such as the influence of noise and the time required to achieve the control are addressed. It is found that the average transient time preceding the control obeys a scaling law that is *qualitatively different* from the algebraic scaling law which occurs when one controls chaos by stabilizing unstable periodic orbits embedded in a chaotic attractor. A theoretical argument is provided for the observed scaling law.

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PS01
Blownout Attractors

Suppose a chaotic attractor A in an invariant subspace loses stability on varying a parameter. At the point of loss of stability, the most positive Lyapunov exponent of the natural measure on A crosses zero at what has been called a 'blowout' bifurcation. There are two types of blowout: subcritical (or hard) and supercritical (or soft). We investigate the dynamical and ergodic properties of nearby invariant sets in both scenarios. Our analytical results center on model piecewise linear planar maps and drift-diffusion systems, but we expect our results to apply to more general systems.

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PS01
Enhancement of Stochastic Resonance of FitzHugh-Nagumo Neuronal Model Driven by $1/f$ Noise

We investigated the stochastic resonance driven by $1/f$ noise in FitzHugh-Nagumo neuronal model by numerical simulation. The system exhibited typical characteritics of stochastic resonance that there is an optimal intensity of noise maximizing the response to subthreshold signals. The optimal intensity of $1/f$ noise was lower than that of white noise by a factor of 1/5. We also discuss the mechanism by which $1/f$ noise could enhance the performance of stochastic resonance in FitzHugh-Nagumo neurons.

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PS01
Nonlinear Pattern Dynamics in Two-dimensional Josephson-Junction Networks

The dynamics of a two-dimensional array of Josepson-junctions is shown to be equivalent to that of a one di-

mensional chain of nonlinear, globally, and nonuniformly coupled oscillators. We describe spatiotemporal patterns, coupled oscillatory compartments and successive bifurcations the array exhibits in response to varying input patterns and bias current. Since boundary instabilities impede coherent microwave radiation emission also in the presence of external loads, a new symmetry-breaking array architecture is designed to achieve coherence.

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PS01

The Construction of the Analytic Periodic Solution in the Framework of the Multiple Time Scale Method

Our main objective is to develop an analytical method for the problem of the domain wall motion. The starting point is the Landau-Lifshitz and Gilbert equations of the magnetic spin system dynamics. Following Sloczewski we study the behavior of the anisotropic magnetics with uniaxial magnetic anisotropy in the z axis direction. The Bloch wall plane is infinity and parallel to the zy plane. An external magnetic acts in the direction of the z axis and the domain wall moves in the direction of the x axis. Having in mind all of this the equation of the Bloch wall motion is

$$\frac{2\mu_0\left(1+\alpha^2\right)}{\gamma^2\Delta}x'' + \left(\frac{8\pi\mu_0 I_s\alpha}{|\gamma|\Delta}+\frac{16dI_s^2}{\pi^3\rho}\right) x' + \frac{2\delta H_c I_s}{l}\sin\frac{2\pi x}{l} = 2I_s H\sin\omega t$$

where d is the thickness of the magnetic material, ρ is the electrical resistivity of the magnetic material. Using the multiple time scales method [?] one finds the analytic periodic solution of the domain-wall motion. The limit cycle solution was theoretically obtained. The stability of the periodic solution was investigated. The periodic windows theoretically found are in good agreement with the experimental and numerical results previously reported.

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PS01

Markov Random Fields and Dynamical Systems with Memory in Pattern Generation and Recognition Processes

We present a stochastic algorithm based on a modified totalistic rule of the Chate-Maneville type. It is used the random Markov field model [?, ?, ?, ?] to generate virtual object. The virtual objects are the elementary cells that generate the desired pattern under proper geometrical operations. The main application of the model concerns pattern recognition. The model is also a realistic base of understanding the emergence of synchronous behavior in physics (chemistry or biology) related to some kind of self organization processes. Our main goal is to understand the process of complex pattern generation and theirs underlying local mechanisms. We previously reported successful theoretical and numerical results on simple pattern generation based on stochastic algorithm [?, ?]. The present studies go further and define explicit algorithm useful to generate any complex pattern. We introduce the new idea of the virtual object, namely, the minimal geometrical structure that generates a pattern. It is also introduced the new method of random Markov field (RMF) to generate virtual pattern. Once upon a virtual object is generated the modified functional self organization (MFSO) stochastic model is used to form clusters (of virtual objects).

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PS01

Scale-sensitive Linear Analysis of Granivorous Rodent Population Dynamics

Traditional linear analysis of ecological systems fails to consider temporal scale–linear regularities may only be visible within a definite time "window." Community matrices at different temporal scales were used to predict the effect of removal of larger granivorous desert rodents on smaller ones. The accuracy of prediction was found to be very scale-dependent; predictions were highly variable, especially at larger time scales. This indicates that linear analysis is an inadequate tool for prediction of perturbation effects in this system.

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PS01

Ionic Diffusion Within the Confined Extracellular Space of Glomeruli

Diffusion in complex media occurs in many important physical and biological contexts. We present a model of this process relevant to the olfactory system. For insects and vertebrates, these systems are similar in the organization of their synaptic neuropil into glomeruli, structures surrounded by an incomplete layer of glial processes. *Why are glial cells in such an organized structural formation?* Is the organization for developmental reasons or does it serve functional purposes? One possible function is the regulation of potassium. A biologically realistic model is derived to examine the diffusion of potassium through the confined extracellular volume of glomeruli. This study will aid in the understanding of the role of glial cells in any general synaptic neuropil.

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PS01

Characterization of noise in electrotelluric time series

In a resent paper[1] it was suggested that the behavior of the so-called electrotelluric field is corrrelated with the

preparation mechanism of eathquakes. That report was concerned with seismic activity in the Pacific coast of Mexico. By means of some of the same electrotelluric files used in the mentionet article, we made a noise analysis. This new study is made by using spectral techniques and also by means of correlation coeficients. Our preliminary results suggest that white noise is predominant in electrotelluric fluctuations. Nevertheless, it seems that there exist another kind of fluctuations which are not of the white noise type. [1] E. Yepez, F.Angulo-Brown, J.A. Peralta, C.G. Pavia and G. Gonzalez-Santos, Geophys. Res. Lett. 22 (1995) 3087.

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PS01

Bifurcations and Edge Oscillations in an Inhomogeneous Reaction-Diffusion System

We examine the influence of inhomogeneity on bifurcations affecting the stability of pulse solutions to certain reaction-diffusion systems. Using the Evans function and a topological stability index, we prove analytically that two bifurcations can destabilize standing pulses, without the inhomogeneity. These bifurcations are analyzed in terms of the eigenvalues involved and the solutions produced. When inhomogeneity is restored, we compute conditions for these bifurcations to become Hopf bifurcations, yielding in-phase and out-of-phase edge oscillations.

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PS01

Breaking the Symmetry of an Attractor Merging Crisis

A dynamical system with a symmetry has an attractor merging crisis when two or more chaotic attractors merge, when varying a parameter, and suddenly a chaotic attractor of higher size appears. In the present work, a parameter set for which the symmetric double-well Duffing oscillator possesses an attractor merging crisis is considered. An external periodic non-harmonic perturbation is used to drive this dynamical system instead of a harmonic function . This driver has a symmetry-breaking effect on the chaotic attractors. Before the crisis, only one of the two coexisting chaotic attractors remains, while the other one becomes periodic. After the crisis, the only chaotic attractor suffers a transition in which a periodic attractor appears on the left and a chaotic attractor appears on the right.

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PS01

A Nonlinear Model to Classify Dynamic Time Series

We present a nonlinear time series model based on a combination of a SETAR(k;l(1),...,l(k)) model and a structure of neural networks. SETAR-models consist of different linear parts linked by a threshold structure. We replace each of them with a neural network, predict following points of a time series by such a model and analyze the learning rate regarding to changes in determinism and stochasticity. Application to the analysis of fetal breathing pattern will be presented

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PS01

Dynamical Behavior of a Model for Hormonal Regulation during the Menstrual Cycle in Women

A four dimensional system of ordinary differential equations with delay was derived for the concentrations of four hormones important for the menstrual cycle in women. The primary components of the model are the regulation of the synthesis and release of luteinizing hormone (LH) and follicle stimulating hormone (FSH) by estrogen (E_2) and progesterone (P_4) and the effects of LH and FSH on the production of E_2 and P_4. The dynamical behavior of this system is investigated numerically and analytically.

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PS01

The Separatrix Map Approximation of Critical Motion in the 3/1 Jovian Resonance

Chaotic asteroidal motion in the 3/1 Jovian resonance is studied in the planar-elliptic restricted three-body problem averaged on the orbital time scale. The regime of motion taking place near chaos border is considered. In low-eccentric modes of long duration, when motion sticks to the chaos border, the motion is shown to be naturally approximated by the separatrix map in Chirikov's form. Parameters of the approximating separatrix map are estimated both analytically and by means of numeric simulation. The analytical and numeric estimates are in close agreement.

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PS01

Intermingled Basins of Attraction: Uncomputability in a Simple Physical System

Recently it has been shown that a symmetrical dynamical system with multiple attractors can have basins of attraction for these attractors which are intermingled in the sense that every initial condition can be perturbed, with positive probability, into a different attractor's basin by an arbitrarily small random change in the location of the initial condition. This has the disturbing consequence that, even if the initial condition is available with infinite precision, finite computation does not allow one to determine with certainty which of the possible types of long term motion the system eventually settles into. We present an example of a physical system with a single symmetry exhibiting intermingled basins. The simplicity of our example suggests that intermingling can occur in common situations encountered in practice.

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PS01

Global Bifurcations in Periodically Driven Zero-Dispersion Systems

The bifurcation analysis for non-chaotic regimes of the recently discovered (Phys.Rev.E **50**, R44 (1994); Phys.Rev.Lett. **76**, 4453 (1996)) new type of nonlinear resonance is carried out by the averaging method. It is shown that the global bifurcations lead to drastic changes of fluctuational transition rates. At higher amplitudes of the periodic drive, global bifurcations of the averaged system indicate chaos in the full system which gives rise to the characteristic narrow-sector-like shape of chaotic regions in the bifurcation diagram.

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PS01

Dimension and KLD Correlation Lengths in a Two-Dimensional Excitable Medium

We present a quantitative analysis of the complexity of spatiotemporal dynamics in a two-dimensional excitable medium. The extent to which disordered states arising from spiral-wave breakup in a simple model of cardiac electrophysiology (the Karma model) are extensively chaotic is assessed. In the extensively chaotic regime, we calculate dimension and KLD (Karhunen-Loève Decomposition) correlation lengths and discuss the utility of these statistics for characterizing the behavior of excitable media.

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PS01

Simulation of the Immune System on Parallel Computers

The impressive advances of computer technology have opened the way to the simulation "in machina" of complex biological systems. One of the most ambitious goals is the simulation of the dynamics of the immune system response to foreign agents. In this paper we present some preliminary results obtained by running the Celada-Seiden immunological automaton on a highly parallel computer.

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PS01

Chemical Mixing using a Chaotic Flow

We consider a chemical mixing device using a chaotic flow under the usual assumption that the reaction rate is sufficiently fast that the efficiency of the reactor is determined by the efficiency of the mixing. The mixing property is given by the time and spatial dependence of the finite time Lyapunov exponent of the flow (e.g. see Physica D **95**, 283-305, 1996). The limitation and optimization of such devices will also be discussed.

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PS01

Signal Compression and Information Retrieval via Symbolization

Converting a continuous signal into a multi-symbol stream is a simple method of data compression which preserves much of the dynamical information embedded in the original signal. For example, correlation timescales can be easily recovered by varying the time delay for symbolization, even at high noise levels. The presence of periodicity in the signal, even if it is weak and the original signal extremely noisy, can also be reliably detected.

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PS01
Symbolic Time Series Analysis of Continuous Dynamical Systems

Symbolic techniques have successfully been used to carry out parameter estimation for systems such as noisy chaotic maps, the Ginzburg-Landau equation, and experimental data. While these results are encouraging, there is much to be learned about symbolization that could potentially improve its usefulness as an experimental tool. We will discuss the effect of varying the two fundamental parameters which define the symbolization: the choice of time delay for sampling and the partition.

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PS01
Invariant Measure for Dynamical Distributed Parameter Systems

We present the existence of a measure invariant with respect to the dynamical systems governed by evolutive partial differential equations of the first order

$$\frac{\partial u}{\partial t} + \frac{\partial (fu)}{\partial x} = \lambda u \qquad (0.1)$$

where we denote $u(x, t)$ as the state variable and assume the following boundary-initial conditions: $u(t, 0) = 0$ for $t \geq 0$ and $u(0, x) = v(x)$ for $0 \leq x \leq 1$, whith $v(x)$ as a known function. The parameter λ can take values in R_+ and have the role of Reynolds number. By motion of (1) we mean a continuously differentiable function $u(t, x)$ for which (1) is satisfied for all $x \geq 0, t \geq 0$. We consider the phenomenon of the turbulence in the state space of the motion. The behavior of the trajectory of the system depends upon λ. For λ sufficiently small ($\lambda < 1$) all motions converge to the laminar motion $u \equiv 0$. For large value of λ ($\lambda \geq 2$) the system admits infinitely many turbulent motions. The purpose of this paper is to show that by use of the method of compact varieties it is possible to construct an ergodic invariant measure for the studied systems. Such form of a measure is positive on open non-empty sets. A relationship between strictly turbulent trajectories and non-trivial invariant measure is established. An application is also presented.

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PS01
Dynamics of Interacting Modes in EEG–Datasets

Results of a spatiotemporal signal analysis applied to two different types of EEG-data are presented: data recorded A) during petit-mal epileptic seizures and B) during a psychological experiment (ϕ - phenomena). In case A) the analysis yields a mode interaction with two different types of Shilnikov dynamics [Friedrich R., Uhl, C., Physica D (in press)]. In case B) oscillatory patterns are observed and their dynamic interaction is investigated. The underlying method of spatiotemporal analysis is shown in a second contribution.

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PS01
Long-Time Term Behaviour of Density Oscillator

We examine the dynamical behaviour of a simple density oscillator of a salt + water aqueous solution. A rhytmic change of the electrical potential, associated with the periodic flow was generated. We have measured the flow and liquid levels under various experimental conditions such as different molarities and several salts. As a result we can found a empirical fitting to the decaying behaviour of the oscillations that depends on a single parameter. The purpose of this work is to look for the dissipative mechanisms by which the density oscillations decaying to reach the equilibrium.

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PS01
Canard Explosion and Bistability in the Belousov-Zhabotinsky Reaction

The Belousov-Zhabotinsky (BZ) reaction displays a rich variety of temporal behaviour, including bistability between a limit cycle and a steady state, and canard explosion, where the amplitude of oscillation appear to jump discontinuously. A review of a codimension three degenerate Hopf bifurcation associated with dynamical effects which could explain these observations will be presented, and various models of the BZ reaction will be tested to determine the parameter ranges where bistability and canard explosion are expected to occur.

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PS01
A Model for Flows with Separation and the Circular Hydraulic Jump

When a liquid jet hits a plate and spreads radially, liquid layer thickness increases suddenly at a certain radius. This familiar phenomenon still remains unexplained due to strong viscous effect and presence of a free boundary. Moreover, our experiment observes many flow patterns and

bifurcations as the flow rate is varied. Since the boundary layer theory, the standard method to treat thin viscous flows, breaks down when separations occur, we construct a model which overcomes this difficulty.

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PS01

Trapping and Wiggling: Elastohydrodynamics of Driven Microfilaments

We present a general theoretical analysis of semiflexible filaments subject to viscous drag or point forcing. These are the relevant forces in dynamic experiments designed to measure biopolymer bending moduli. By analogy with the "Stokes problems" in hydrodynamics (fluid motion induced by that of a wall bounding a viscous fluid), we consider the motion of a polymer one end of which is moved in an impulsive or oscillatory way. Analytical solutions for the time-dependent shapes of such moving polymers are obtained within an analysis applicable to small-amplitude deformations. In the case of oscillatory driving, particular attention is paid to a characteristic length determined by the frequency of oscillation, the polymer persistence length, and the viscous drag coefficient. Experiments on actin filaments manipulated with optical traps confirm the scaling law predicted by the analysis and provide a new technique for measuring the elastic bending modulus. A re-analysis of several published experiments on microtubules is also presented.

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PS01

Chaotic Communications in the Presence of a Wireless Channel

This work considers the performance of a number of communication methods using chaotic continuous time systems. The communication problem is addressed in two stages, the synchronisation method and the information encoding/decoding scheme. In particular we consider the effect of a distorting and noisy channel on a variety of performance measures (such as statistical analysis of the error signal and Bit Error Rate). Orthogonality in multi-symbol code sets is also presented.

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PS01

The Method of Melnikov for Perturbations of Multi-Degree-of-Freedom Hamiltonian Systems

We develop a Melnikov-type global perturbation technique for detecting the existence of transverse homoclinic orbits and occurrence of homoclinic bifurcations in periodic perturbations of multi-degree-of-freedom Hamiltonian systems. The unperturbed system is assumed to have a saddle-center whose stable and unstable manifolds do not coincide but intersect in a lower-dimensional manifold, and does not have to be completely integrable. Other Melnikov-type methods do not apply in this situation. We also apply our technique to a four-degree-of-freedom model of a non-planar vibrations of a forced, buckled beam.

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PS01

Chaotic Scattering in Micro Lasing Cavities

Optical processes in microcavities have been a subject of intensive study. These cavities can support high-Q whispering gallery (WG) modes due to total internal reflection of the trapped light. However, inevitable deformations can lead to the Q-spoiling of WG modes. We show that such modes can be studied via chaotic scattering. We also identify the dynamical invariants that can be related to Q-spoiling.

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PS01

Clusters in Globally Coupled Assemblies of Bistable Elements

Assemblies of oscillators the bistability of which is caused by phase effects such as the compensation of frequency mismatch δ and its variations due to nonlinear effects (G.V. Osipov, M.M. Sushchikk, Phys. Lett. **A201**, 1995, 205–212) are investigated. In the case of "all-to-all" coupling, multistability occurs in such assemblies, i.e., there exist the clusters having a different number of excited elements. The features inherent in the phase mechanism of formation of the bistability of such an oscillator result in nontrivial effects accompanying the interaction of such assemblies. In particular, it was revealed that when a "minimal" cluster (i.e, with one excited element) of one assembly is coupled with a large cluster ($N_c \gg 1$) of another assembly, one element of the large cluster passes over to an unexcited state, while the minimal cluster persists to be in the excited state.

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PS01
Extensive Chaos and Unstable Periodic Orbits

Unstable periodic orbits (UPOs) associated with chaotic systems may provide an important method for analyzing and controlling high-
dimensional spatially extended chaos. Using new efficient algorithms to systematically calculate UPOs for partial differential equations with general boundary conditions, we report the first calculations of UPOs for an extensively chaotic system (the 1d Kuramoto-Sivashinsky equation) and discuss some implications of these orbits for control and synchronization.

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PS02
Control of Impact Dynamics

In this paper we show a successful numerical control of periodic motion exhibited by one- and two-degree-of-freedom mechanical systems with impacts. This approach includes two new aspects. 1. We demonstrate a possibility = of stability improvement of the considered periodic motion, using MATLAB-Simulink package. 2. We propose an original analytical technique applied to a one-degree-of-freedom system to predict the efficient delay loop coefficients in order to achieve a desired stabilization. The last item is based on the introduction of a special "impact" map, and then the problem is reduced to consideration = of the difference equations instead of differential equations.

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PS02
Type-II intermittency in the driven Double Scroll Circuit

In this work, we show experimental evidences, confirmed by numerical results, from type-II intermittency in the driven Double Scroll Circuit. Numerically, we found a new scaling power law dependence on the critical parameter. This result is a consequence of the first identified global bifurcation scenarium for the T^2 torus breakdown observed in this system: a heteroclinic saddle connection is the nonlinear mechanism responsible for the reinjection of the trajectory around a repellor focus. In fact, in this global scenarium the total laminar phase is the spiraling laminar period (usually considered) plus the time the trajectory spends in the vicinity of the saddle points.

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PS02
Pattern Formation Inside a Laser Spectrum

The multimode class-B laser can behave as a chain of locally coupled oscillators, each associated to one longitudinal mode. In such a laser, one can consider the set of modes as a spatiotemporal system in which waves can propagate. We report on the observation of dispersion-induced patterns in a multimode laser subjected to pump modulation. In particular, a parametric "Faraday-like" instability is evidenced analytically, numerically, and checked experimentally on a Nd-doped fiber laser.

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PS02
Knot-Theoretic Analysis of Low-Dimensional Attractors

When embedded in a three-dimensional attractor, the intertwining of unstable periodic orbits (UPO) can be analyzed using knot theory. A systematic study of their topological organization is allowed by the existence of a branched manifold, the template, on which all the UPO can be projected while preserving their knot invariants. This approach can provide a clear-cut answer to whether a model is compatible with experimental data and can be used to construct symbolic encodings.

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PS02
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PS02

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PS02

Numerical Simulation of Standing Waves in a Vertically Oscillated Granular Layer

Parametric standing wave patterns spontaneously form in a numerical simulation of vertically oscillated granular layers. Particles are modeled as spheres that collide inelastically, conserving momentum. The particles interact only on contact; between collisions particles move ballistically. Spatial patterns form when the container acceleration amplitude exceeds a critical value. The dependence of the wavelength (typically 20 sphere diameters) on frequency determined in the simulations is in agreement with experiments in our laboratory on oscillated granular layers.

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PS02

Modular Networks for Animal Gaits

The gaits of quadrupeds, walk, trot, etc., can be described by spatio-temporal symmetries of periodic functions. We model gaits by periodic solutions to coupled systems of identical ODE's (or cells) with leg permutation symmetries. We show that four cell models cannot produce walk and trot without leading to an undesired conjugacy between trot and pace. We circumvent this difficulty with a modular eight cell model; one real and one virtual cell for each leg. Our model scales to many-legged animals.

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PS02

Dynamics of the Two-Frequency Torus Breakdown in the Driven Double Scroll Circuit

In this work we identified two scenarios for the two-frequency torus breakdown to chaos in the driven Double Scroll circuit, for varying driven parameters. One is through the Curry-Yorke route to chaos. For this route we identified numerically the transition to chaos through the onset of a heteroclinic tangle and its heteroclinic points. The other scenario is through the appearance of type-II intermittency for wich a quasiperiodic torus grows in size, and breaks by touching external saddle points, forming a heteroclinic saddle connection. This two identified dynamic scenarios have two distinct structure evolution for a varying driven parameter. Chaos (measured by the Lyapunov exponents) in Curry-Yorke scenario appears very softly and alternates with phase-locking while, through type-II intermittency, chaos appears abruptally and is preserved for a large range of the varying driven parameter.

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PS02

Optimal Dynamic Nonlinear Pricing and Capacity Planning

Physically constrained subscription-based telephone network services like cellular telephone can experience opposing market forces which affect new product adoption. In such networks, a positive demand externality due to increases in subscribership encourages more subscribers to sign up whereas a negative externality in the form of congestion discourages subscriber set expansion. Dynamic nonlinear pricing and capacity planning strategies are solved for analytically and numerically in an optimal control framework.

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PS02

Stationary Solutions of an Integro-Differential Equation Modeling Phase Transitions: Existence

and Local Stability

We study stationary solutions of the scalar equation

$$u_t = J * u - u - f(u)$$

This equation arises in e.g., non-local phase transition theory. Existence of various types of patterns is analyzed through phase-plane, homotopy and variational methods. Local stability/instability of those solutions is studied with the help of linearized operators and the maximum principle.

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PS02
Persistence of Compact Invariant Sets and Spectral Properties

We discuss the persistence of compact invariant sets for ordinary differential equations under time-dependent perturbations and the behavior of the Lyapunov exponents under these perturbations. Using the concept of Morse spectrum recently introduced by the authors (TAMS (1996), to appear), we prove semicontinuity properties

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PS02
Lattice Boltzmann Equation Model for Potassium Dynamics in Brain

In the brain, potassium dynamics is constrained by extra- and intracellular diffusions, by active and passive transports across cell membranes, and by the spatial buffering mechanism. In addition, the complex brain geometry imposes constraints on the diffusion process. It is difficult to study such a complex system using conventional methods. Therefore, we build a lattice Boltzmann equation model for this system. Numerical simulations on this model are performed, and the numerical results for the brain as a porous medium reproduce qualitatively the behavior of potassium movements obtained from the experiments with brain tissue. As applications of the model, we study the effects of specific mechanisms on the clearance of potassium after potassium is injected into the extracellular space. We find that various characteristics of the brain, e.g., geometry, affects the clearance of potassium. The geometrical effects suggest that age-related potassium clearance is partly due to age-related brain geometry changes.

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PS02
Chaos and Crises in More than Two Dimensions

Noisy chaotic trajectories with Lyapunov exponents that fluctuate about zero are basically unshadowable. This can occur when periodic orbits with different numbers of unstable directions coexist inside the attractor. The presence of a Henon-type chaotic saddle guarantees such coexistence in a persistent manner. In this talk we will describe how these sets appear naturally in maps of more than two dimensions, how they can be found and what crises they produce.

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PS02
Discontinuous Bifurcations and Crises in a DC/DC Buck Converter

In our talk, we will discuss the analysis of nonlinear phenomena in the voltage controlled DC/DC buck converter. While previous numerical and experimental investigations have shown that nonlinear phenomena are indeed present in the real circuit, no analytical investigations has been carried out due to the discontinuous nature of the system involved. By using a new kind of discrete-time mapping, the *impact map*, we will show how conditions of existence for several periodic solutions can be given and how the Jacobian of the map can be derived analytically, allowing the calculation of several bifurcation points. Moreover, we will give an explanation for the sudden enlargement of the attractor, exhibited by the circuit, and show that its structure is organised around an unstable five-periodic solution which exists over a large range of the bifurcation parameter and which has a large stable manifold. All through the talk, we will present both experimental and simulation results, which confirm what stated analytically.

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PS02
Resonance Zones for Henon Maps

A resonance zone is a compact set in the plane which is bounded by alternating initial segments of stable and unstable manifolds of saddle points. The analysis of resonance zones in terms of their exit time decompositions is still not complete, and the goal of this work is to provide examples of different zones where a detailed combinatorial analysis is possible. A new study of transport between adjacent zones is initiated. Area preserving Henon maps are used to provide examples.

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PS02

On Some Random Generalized Functions Having a Mean

In previous work, classes of random periodic distributions and, of random tempered distributions, were introduced, using conditions on the (random variables) coefficients sequence, of the Fourier and Hermite series expansions of these random distributions. The conditions can be shortly stated as follows: the sequence of the coefficients, of the Fourier or Hermite series expansion, is a sequence of random variables whose expectations form a numeric sequence of slow growth. It was shown that these condition characterises the random periodic (or tempered) distributions having a mean. We present now, an extension of previous results to random distributions defined on manifolds, by using the local character of the concept of mean of a randon distribution.

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PS02

A Feedback Scheme for Controlling Dispersive Chaos in the Complex Ginzburg-Landau Equation

Experiments on convection in binary fluids in a narrow geometry exhibit irregular bursting behavior termed "dispersive chaos". This system can be modeled by a complex Ginzburg-Landau equation with a large negative nonlinear-dispersion coefficient c_2:
$(\partial_t+s\partial_x)A=\epsilon(1+ic_0)A+\xi_0^2(1+ic_1)\partial_x^2A+g(1+ic_2)\,|A|^2\,A.$
We have suppressed dispersive bursting in numerical integrations of this equation by applying a nonhomogeneous stress parameter ϵ' which is computed from the phase Φ of the complex variable A: $\epsilon'=\epsilon+f(\Phi)$. We also investigate the stability of the resulting profile.

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PS02

Causal Bifurcation Sequences in Systems Containing Strong Periodic Forcing

A causal bifurcation sequence is defined here to be composed of codimension-1 local bifurcations, global bifurcations and scenarios, produced by the variation of a single parameter in a dynamical system. I will consider an observed predator-prey model behavior in which chaotic sets with symmetry evolve from attracting to transients and back to attracting. For this example, it is possible to determine a complete set of bifurcation sequences giving rise to full or partial dynamics.

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PS02

Image Encryption Based on Chaos

We present an application of two dimensional chaotic maps to image encryption. A two dimensional chaotic map on a torus is first generalized by introducing parameters, then it is discretized and extended to three dimensions. When applied to a digital image, it creates a complex permutation of pixels and gray levels. The encrypted image has a uniform histogram and resembles an uncorrelated static on a TV monitor without signal. The parameters of the chaotic map serve as the secret key. It is shown that sensitivity to initial conditions and mixing guarantee good encryption properties. The baker map, cat map, and generalized standard map are studied. Besides the applications in cryptography, the research contributes to the study of chaotic maps on periodic lattices as round-off approximations to area-preserving maps on a torus.

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PS02

Steps Toward the Long-Term Simulation of Turbulent Flows through Higher-Order Incremental Unknowns/Hierarchical Basis

Higher-order incremental unknowns/hierarchical basis are introduced, in the context of finite-difference methods, to construct effective numerical algorithms by using approximate inertial manifolds in order to study the long-term dynamic behavior of nonlinear dissipative evolutionary equations; we consider the one-dimensional Kuramoto-Sivashinsky equation (periodic hierarchical basis) and the two-dimensional incompressible Navier-Stokes equations (truncated hierarchical basis). The underlying matricial techniques are discussed in detail and an up-to-date overview of the higher-order incremental unknowns methodology is presented.

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PS02

Influence of Measurement Desynchronization on Dynamics of Ship Motion Control System

We consider the ship motion control system which includes discrete-time meters and a discrete-time controller. The measurements of ship phase coordinates are performed in the instants between two consecutive reverses of the rudder. The control system is called desynchronized with respect of measurements if the instants of measurements and formation of the rudder reverses are distinct. Otherwise, it is called synchronized. The particular value of the rudder reverse is defined regardless of time shifts between measurement and control instants. It leads to a change in dynamics of controlled ship motion. This change can be characterized by shifts of the eigenvalues of the matrix which describes a closed loop discrete control system. The estimates of these

shifts for a tanker are obtained.

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PS02

Theoretical Analysis of Pattern Formation in Circular Domains

Experiments on a circular flame front exhibit a variety of stationary and non-stationary cellular states. Numerical integration of a model system with circular boundaries is shown to exhibit similar states. It is shown how the states result from the mode coupling between "rings of cells" with different symmetries. In particular, mode-couplings that are not naturally present in one dimensional systems, are shown to play a part in "hopping" and "ratcheting" states of cells.

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PS02

Multi-Parameter Bifurcation Analysis in Nonlinear Control Systems

This paper addresses the problem of probing the spectrum of behaviour of a nonlinear control system when analysed in the context of a multi- parameter bifurcation problem. Using a combination of local and global numerical methods a hybrid framework of analysis is developed, which proves to be useful in uncovering the characteristics of a wide variety of nonlinear continuous and discrete or sampled data control systems. A number of examples are included to illustrate the framework of analysis.

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PS02

Stick-Slip Dynamics and Friction in an Array of Coupled Nonlinear Oscillators

We present the results of our study of stick-slip motion in a 1D array of nearest-neighbor coupled nonlinear oscillators, all subject to the same external force. Our motivation is to study friction and the underlying mechanism leading to stick-slip motion in the strongly nonlinear regime. We have developed simple formalism to reduce the complexity of the equations and to calculate the velocity and the friction coefficient of the elements in the array as a function of the driving force f. For $f < f_c$ only stick behaviour occurs, but for $f > f_c$ stick-slip motion takes place with a dramatic increase in the sliding friction coefficient $\propto N(f-f_c)^{-1/2}$ as $f \to f_c$, where N is the number of oscillators in the array, due to the existence of a universal saddle-node bifurcation in the dynamics.

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PS02

Using Manifolds to Generate Trajectories for Libration Point Missions

Recently, there has been accelerated interest in missions utilizing trajectories near libration points. The trajectory design issues involved in missions of such complexity go beyond the lack of preliminary baseline trajectories. Successful and efficient design of mission options requires new perspectives and a more complete understanding of the solution space. Dynamical systems theory has been applied to better understand the geometry of the phase space in the three-body problem via stable and unstable manifolds. Then, the manifolds are used to generate various solution arcs and establish trajectory options that have been utilized in preliminary design for various proposed missions.

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PS02

Manifold Reduction and Flow Reconstruction Using Karhunen-Loeve Transformations and Neural Reconstruction

In this talk, I discuss the concept of *neural charts*. Given a flow in high-dimensional space from which there exists an approximating manifold, the neural charts algorithm is designed to produce a local, low-dimensional, semi-analytic (nonlinear) approximation to the manifold. From this description, we can then develop local low-dimensional models of the flow. Examples will come from the Kuramoto-Sivashiski Equation and the Mackey-Glass differential-delay equation.

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PS02

Applications of the KAM Theory to Commensurate-Incomensurate Phase Transitions

This paper gives a brief review of some of our recent works in the the applications of the KAM thory to commensurate-incommensurate (CI) phase tranistions. We use a simple one-dimensional model called the Frenkel-Kontorova (FK) model to describe CI transitions and vaious forms of the interparticle and external potentials are used. Many interesting and new results have been obtained.

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PS02

Computation of Invariant Tori Near L_1 in the Earth–Sun System

The final goal of this work is to describe the dynamics near the Lagrangian point L_1 of the real Earth–Sun system. The first step is to build a suitable model, based on the Earth–Sun Restricted Three Body Problem plus quasiperiodic time-dependent perturbations coming from the real motion of the bodies of the Solar system. Then, using normal form techniques, we will compute several invariant tori as well as integrable approximations to the dynamics, that allow to give a complete description of the solutions nearby.

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PS02

Finitely Representable Set-Valued Maps and Computation of the Conley Index

The class of representable usc multivalued maps is discussed. Such maps first appeared in the Mrozek-Mischaikow proof of chaos in the Lorenz equations. Given a continuous map f in an euclidean space, its cubic-valued representation F can be computed. Iheritable properties of F are used to provide algorithmic constuctions of isolating neighbourhoods, index pairs, the homomorphisms induced in homology by f and, finally, the Conley Index of f.

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PS02

Dynamics of the Ginzburg-Landau Equations of Superconductivity

In the one-parameter family of "$\phi = -\omega(\nabla \cdot \mathbf{A})$" gauges ($\omega > 0$), the time-dependent Ginzburg-Landau (TDGL) equations of superconductivity define a *dynamical process* when the applied magnetic field varies with time and a *dynamical system* when the applied magnetic field is stationary. When the applied magnetic field is stationary, every solution of the TDGL equations is attracted to a set of stationary solutions, which are divergence free. When the applied magnetic field is asymptotically stationary, the dynamical process is asymptotically autonomous and approaches a dynamical system, whose attractor coincides with the omega-limit set of the dynamical process.

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PS02

Chaos Synchronization and Riddled Basins in Two Coupled One-Dimensional Maps

The connection between chaos synchronization and phenomena of riddled basins is disscused for a family of two-dimensional piecewise linear endomorphisms which consist of two linearly coupled one-dimensional maps. Under analytically given conditions chaotic behavior in both maps can synchronized but synchronized state is characterized by different types of stability. The mechanism of occurrence of riddled basins is described in details.

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PS02

Dichotomies and Numerics of Stiff Problems

Stiff problems are a classical problem in numerical analysis of ordinary differential equations. In a quantitative way the problem is stiff, if the linearization of the vector field along a solution has an exponential dichotomy with widely separated constants. We show that the existence of a similar discrete dichotomy for the linearization of a given discretization method is an efficient and unifying criterion for the suitability of the discretization method for stiff problems.

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PS02

Application of the Theory of Optimal Control of Distributed Media to Nonlinear Optical Fiber

Soliton propagating in optical fiber amplifiers lose ideal soliton shape and nonsoliton radiation appears. We consider the optimal control problem for distributed media with functional describing deviation of ideal soliton with increasing amplitude from real solution subject to the Nonlinear Schredinger Equation with variable coefficients with gain $\gamma(z)$ as control. Obtained analytical solution describe optimal amplification of solitons without formation

of nonsoliton radiation. Method was applied also for phase-sensitive amplifier and for timing jitter effect.

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PS02

When Can a Dynamical System Represent an Irreversible Process

Processes, **V**, which are both extremal and reversible do not exist for symplectic (non-canonical) 4D physical systems defined by a 1-form of action, A. Evolutionary vector fields must admit anholonomic differential fluctuations in position (Δx˜pressure) and/or in velocity (Δv˜temperature). If $\Delta x = 0$, a kinematic dynamical system exists which represents an irreversible process when the virtual work 1-form W=i(**V**)dA is not closed.

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PS02

The Computer Analysis of Poincare Cross-Sections in Chemical Reactions Dynamics

There are some ways to investigate chemical dynamics which is described by a system of ordinary differential equations. One of them is based on the analysis of coefficients of characteristic polynom. The computer realization of this way is given in papers. Another way is construction and analysis of Poincare cross-sections for trajectories of the investigated system. We worked out the computer program which constructs Poincare cross- sections according to the below-described algorithm of the system of differential equations of chemical kinetics. A hyperplane which contains a special point of the investigated system and which divides n-measured phase space into two regions is chosen. A multitude of points forming Poincare cross-sections are obtained on the base of the data on the dependence of time change of the concentration of the one of reacting substances and cross-section points of this dependence with the hyperplane. The dynamics character of an initial chemical system can be established according to the topological properties of an obtained cross-section. For example, if the solution of the differential equation system is periodic, then the corresponding Poincare cross-section is either one point or some points. In this case the terminal cycle is twisting. For decaying periodic oscillations many points are formed which direct to the single terminal point which correspond to the focus on a phase portrait. The program was applied to the investigation of self-oscillations in heterogeneous catalytic reaction kinetics.

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PS02

The Modellong of Self-Oscillating Regimes in Catalytic Reaction Dynamics

While investigating kinetic regularities of a number of chemical catalytic reactions, decaying, regular and relaxing oscillations were experimentally found. The establishment of interrelation between the reaction mechanisms and oscillation forms is of some interest. It is known that for the describing of decaying oscillation it is quite enough to use three and more stage linear reaction schemes which are characterized by a single steady inner stationary state (ISS). If there is a single unsteady ISS, then non-decaying, regular and relaxing oscillations arise. Such regimes are characteristic for reactions which proceed via three and more stages when not less than two independent intermediate substances take part. They are to satisfy some definite requirements on stoichiometry. The systematization of all possible mechanisms describing auto-oscillating regimes was done corcerning the group of three- and four-stage reactions. For the analysis of the schemes of such reactions we determined the common stoichiometric conditions of unstability which help to identify the reaction schemes describing non-decaying oscillating regimes. The requirement of singularity of ISS is taken into account. For the systematization of mechanisms a computer programm was compiled which includes the following subprograms: the generation of mechanisms which are not repeated; the analisys of unstability and singularity of ISS. Due to this program the classification of three- and four-stage mechanisms was done. The application of generated mechanisms in reactions of CO and H2 oxidation on platinum metals was investigated.

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PS02

Scaling Behavior of Transition to Chaos in Quasiperiodically Driven Dynamical Systems

A route to chaos in quasiperiodically driven dynamical systems is investigated whereby the Lyapunov exponent passes through zero linearly near the transition. A dynamical consequence is that, after the transition, the collective behavior of an ensemble of trajectories on the chaotic attractor exhibits an extreme type of intermittency. The scaling behavior of various measurable quantities near the transition is examined.

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PS02

Noise-Induced Riddling in Chaotic Systems

Recent works have considered the situation of riddling where, when a chaotic attractor lying in an invariant subspace is *transversely stable*, the basin of the attractor can be riddled with holes that belong to the basin of another attractor. We show that riddling can be induced by arbitrarily small random noise *even if the attractor is transversely*

unstable, and we obtain universal scaling laws for noise-induced riddling. Our results imply that the phenomenon of riddling can be more prevalent than expected before, as noise is practically inevitable in dynamical systems.

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PS02
Stacked Lagrange Tops: Analysis of Multi-Component Systems

Techniques from geometric mechanics and numerical analysis can be combined to efficiently study large nonlinear systems. Systems of coupled rigid bodies are an important class of such systems. A representative example consists of a collection of Lagrange tops linked along their axes of symmetry and moving under the influence of gravity. The tops can undergo steady motions consisting of combinations of spins about their axes of symmetry and an overall spatial rotation. The equations determining such steady motions are essentially linear and the structure of the relevant matrices leads to easily evaluated criteria for the existence and stability of steady motions. Any such matrix can always be expressed as the sum of a triangular matrix and a rank one matrix; those associated to steady motions such that the axes of symmetry of the tops do not all lie in a common vertical plane, have an additional 'overlapping block' structure. The stability of the relative equilibria can be studied using the reduced energy momentum method of Simo et al.. Sharp, simple, and physically intuitive stability conditions can be found for several classes of steady motions; these classes exist for arbitrarily large collections of tops.

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PS02
Recurrent Propagation of a Wave Front in an Excitable Medium

We illustrate how a diffusable substance that is concentrated locally in a finite domain of space may spread out in the form of a spatially recurrent wave. Here, *spatially recurrent wave* refers to a wave front that repetitively reverses its direction and returns to the site of its origin before reaching out further in the space. Such recurrent waves arise in a set of 3 partial differential equations (with only 1 diffusable variable) that describes the propagation of calcium waves observed oocytes. A Fitzhugh-Nagumo analogue of such equations is formulated and analyzed.

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PS02
The Invariant Manifolds and Solar System Dynamics

We present a simple model of the solar system using a series of planar circular restricted three body systems. Numerical computations of the invariant manifolds provide a remarkable picture of the choatic diffusion process within the solar system. This is not Arnold diffusion since the system has only two degrees of freedom and is not near-integrable. This diffusion process is the basis for much of the dynamics of the solar system. It brings together many disparate phenomena within solar system dynamics and provides a coherent and simple explanation for their behavior.

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PS02
Transport Properties in Disordered Ratchet Potentials

The role of disorder in one-dimensional periodic ratchet potentials is investigated by introducing: (i) *impurities* – a certain fraction of the asymmetric unit cells are replaced by unit cells with opposite asymmetry; (ii) *randomness* – all unit cells have the same asymmetry, but random size. The relevant color induced currents are determined and compared with the current in the ideal periodic ratchet potential. Altogether, disorder is shown to quench the effectiveness of thermal ratchets, while novel transport properties become detectable.

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PS02
Dynamical Precursor of Black Hole Formation Numerical Simulation

The formation of a massive black hole in a galactic center requires a dynamical mechanism for the concentration of mass in a self gravitating system. Thermodynamics suggests the possibility of a density singularity. Here we investigate the dynamics of a system of concentric spherical mass shells constrained by an inner and outer reflecting barrier. We show that, as the inner barrier becomes small, a transition is observed and we find coexistence between an extended and a condensed phase.

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PS02

Integrals of Motion and the Shape of the Attractor for the Lorenz Model

In this work, we consider three-dimensional dynamical systems, as for example the Lorenz model. For these systems, we introduce a method for obtaining families of two-dimensional surfaces such that trajectories cross each surface of the family in the same direction. For obtaining these surfaces, we are guided by the integrals of motion that exist for particular values of the parameters of the system. Nonetheless families of surfaces are obtained for arbitrary values of these parameters. Only a bounded region of the phase space is not filled by these surfaces. The global attractor of the system must be contained in this region. In this way, we obtain information on the shape and location of the global attractor; this information can be used to improve the calculation of the Lyapunov exponents of the attractor.

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PS02

Two-dimensional Josephson-Junction Network Architecture for Maximum Microwave Radiation Emission

We design a two-dimensional Josephson-junction array architecture such that all array oscillators self-synchronize into a coherent in-phase state with maximum microwave radiation output in the entire frequency range. Flux quantization implies a global current coupling scheme so that the in-phase oscillation is a global attractor of the nonlinear network dynamics independent of initial conditions, noise and junction imperfections. The microwave power coupled to a matched load depends only on β_c and the size of the array.

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PS02

Scaling in Forced Laser Synchronization

We have found a scaling law for the loss of forced synchronization in single-mode lasers. The degrading parameters are the corresponding cavity frequency and the atomic frequency of the synchronizing lasers. There is a small region in the parameter space of the frequencies where the scaling law breaks up. The corresponding scaling exponents are universal in the sense that they do not depend on the laser operation regime or whether the laser belongs to class-A, class-B or class-C.

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PS02

Lyapunov Exponents from the Dynamics of Classical and Quantal Distributions

We present the first analytically derived asymptotic-time diagnostic for chaos in the dynamics of distributions in a Hamiltonian system. We establish that in a chaotic system a phase-space distribution acquires structure at increasingly smaller scales at an exponential rate given by the largest Lyapunov exponent of the point dynamics. Our final expression for the Lyapunov exponent is trajectory independent: We show how this method may be applied, for instance, in the case of chaotic advection of passive scalars in fluid dynamics. We also apply this method to the classical and quantal Cat Map and show that the $\hbar \to 0$ limit of the quantum map yields the classical, fully chaotic, result. We also demonstrate that chaos is supressed as $\hbar$ increases and the growth of structure saturates at $\mathcal{O}(\hbar)$.

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PS02

A Master Stability Function for Synchronization in Coupled Arrays of Oscillators

It's well know from past work that it is possible to synchronize coupled oscillators, whether chaotic or limit cycle. We show here that it is possible to solve, once and for all, the stability problem of synchronizing any array of identical oscillators. The scheme which gives a master stability function will work for any array of linearly-coupled oscillators. We apply this to a system of 8 coupled Rossler-like circuits.

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PS02

On a Certain Class of Zero-Sum Discrete-Time Stochastic Games

We develop some aspects of a two-players zero-sum stochastic dynamic game theory for a class of discrete-time nonlinear dynamic systems which depends on upon a jump parameter. We consider the class of Markovian Strategies. The concept of *ess inf (sup)* in conjunction with the notion of *Markovian bifurcation* devised here, and a certain consistency property, are the cornerstone of our work. Relying on these elements we derive, *inter alia*, the following results:

1- The saddle point is generically characterized in two different ways: via a *probabilistic principle of optimality* and also from a *martingale point of view*;

2- A *stochastic Isaacs* equation.

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PS02
Flow-Reversal Systems with Fast Switching

We present a class of dynamical systems described by a composition of two conjugated flows. This class of systems arose from experimental studies of catalytic reactors with periodic flow-reversal. We present an abstract framework for such systems and some results of numerical experiments revealing a rich structure of spatio-temporal chaos. Then we focus at the "fast switching" for finite dimensional flow-reversal systems and use linearization and Campbell-Baker-Hausdorff formula to obtain approximations of the asymptotic behavior of such systems.

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PS02
Sudden Changes of Invariant Chaotic Sets in Planar Dynamical Systems

We investigate the nature of sudden discontinuous changes in invariant sets as a parameter is varied by analyzing the behavior of different crises and metamorphoses occuring in 2D invertible maps of the plane. This leads to a generalization of the notions of crises of chaotic attractors and metamorphoses of basins boundaries to the occurrence of sudden changes of chaotic invariant sets in general.

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PS02
Pulse Like Spatial Patterns Described by Higher Order Model Equations

We studied the stationary solutions of the equation

$$u_t = -\gamma u_{xxxx} + u_{xx} + f(u). \tag{1}$$

Of particular interest to us were equations in which f is such that the related equation $u_t = f(u)$ has two stable states $u = u_\pm$ separeted by one unstable state $u = u_0$. A typical function f is

$$f(u) = (u-a)(1-u^2) \quad \text{for} \quad a \in (-1,1). \tag{2}$$

We sought solutions u of the equation

$$\gamma u_{xxxx} = u_{xx} + f(u). \tag{3}$$

Consistent with (2), we required that

$$(u, u', u'', u''') \to (1,0,0,0) \quad as \quad x \to \infty. \tag{4}$$

The presentation is concerned with some qualitative properties of solutions u of Problem (3), (4) without making a-priori restrictions that they are even or monotone.

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PS02
Instabilities of Hexagon Patterns in a Model for Rotating Convection

When rotation about a vertical axis breaks the chiral symmetry in a convection system, the Küppers-Lortz instability leads to a switching between convection rolls of different orientations. If the vertical reflection symmetry is broken hexagonal patterns arise. We investigate in an extended Swift-Hohenberg equation whether a Küppers-Lortz type instability can arise for hexagons; i.e. whether the hexagons can be unstable to hexagons rotated at an angle $\phi \neq 60^o, 120^o, \ldots$. Numerical analysis will determine the nonlinear behavior.

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PS02
Classification of Nonlinear Time Series using Cluster Analysis

We address the problem of distinguishing different dynamical states of a system, based on time series data. Usually, this is done by measuring one or a few characteristic quantities. Then these quantities are arranged into groups. We propose to avoid this severe reduction of information by comparing the time series directly, not via estimates of parameters. A dissimilarity matrix, as obtained e.g. from nonlinear cross-predictions, can then be used to form groups of similar signals.

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PS02
The Geometric Phase in a Point Vortex Flow in a Circle

The existense of a geometric phase is shown in the adiabatic evolution of the angle variable of a fluid particle in a

planar inviscid, incompressible point vortex flow in a circular domain. The velocity field is the linear superposition of that due to an isolated vortex in an unbounded plane and that arising due to the circular boundary. The latter field makes the point vortex in any eccentric position move in a circular path with constant frequency and introduces time-varying periodic coefficients, due to the circular motion of the vortex, in the equations of motion of the fluid particle. We set up a non-dimensional time period T which grows without bound as the fluid particle approaches the parent vortex and, thus, defines an adiabatic process. The periodic coefficients can then be viewed as varying on a "slow" time. Using classical multi-scale asymptotics we then show that the leading order term in the angle variable of the fluid particle decomposes into a! "fast" term and a "slow" term. The value of the "slow" term at the end of the period T is shown to be independent of T. Further, it is expressible as the integral of a 1-form defined on $\mathbf{R}^2 - \{0\}$ around the circular path of the vortex and is therefore identified as a geometric phase.

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PS02
Nonlinear Dynamics of Discrete Ecosystem Models Subject to Periodic Forcing

Discrete ecosystem models are, in general, nonlinear, multi-species, and involve difference equations containing control parameters that relate to such properties as the intrinsic growth-rate of a species. To simulate seasonal effects, we subject to periodic forcing the control parameters in well-known one-species models, including those of May, Moran-Ricker, and Hassell, and also a Maynard Smith predator-prey model. Rich dynamical behavior, including chaos, is found in each model for certain forcing amplitudes and frequencies.

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PS02
The Moving Singularities of the Perturbation Expansion of the Classical Kepler Problem

The convergence properties of the perturbation expansion for the periodic solution of the Kepler problem are discussed as a function of an "amplitude" parameter a associated with the solutions. An infinite number of movable singularities occurring the complex a-plane as conjugate pairs are found to cause the divergence of the perturbation solution. The movable singularities occur at locations where the differential equation under consideration is singular. These singularities can explain the nonuniform convergence noted by Melvin (1977) in his study on constructing Poincare-Lindstedt series for a class of differential equations of oscillator type. Analysis near one of the complex singularities indicates that distinct branches of solution occur there. These solutions undergo transition at the singularity to develop into new solution branches with distinctively different properties. Moving singularities similar to those for the Kepler problem were found in a previous study on the limit cycle of the Van der Pol's equation (1990, 1984). The recurrence of this phenomenon in the present problem suggests that it is very likely to affect convergence of the perturbation series for periodic solutions of other differential equations.

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PS02
Can Markoff Chain Theory Determine a Signals Origin: Chaos or Random?

We present a hypothesis test that can be used to place limits on the likelihood of randomness in complex time series. This process uses time based clustering to transform the original time series into a symbol string, that is analyzed for symbol combination exclusions. These exclusions are easily visualized by using an Iterated Function System Map. Finally, the hypothesis test is implemented using Markoff chains to calculate the probability of missing and existing symbol combinations.

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PS02
Deterministic chaos and analysis of singularities

Of practical interest to us is the transition from chaotic to nonchaotic dynamics in Hamiltonian systems. This transition plays a fundamental role in a very wide variety of physical, chemical, etc. problems (turbulence in incompressible fluids, scattering of atoms from metal surfaces, complex formation in atom-diatom collisions, etc.).
We study this phenomenon on the example of singularly perturbed equation $\epsilon^2 \frac{d^4y}{dx^4} + \frac{d^2y}{dx^2} = y^2 + y$, where ϵ is a small parameter. The subject of our interest are deformations of the homoclinic (separatrix) solution $y = 1.5 \sinh^{-2}(x/2)$ to the nonperturbed equations. Starting with the Kruskal-Segur method of "asymptotic beyond all orders", we show that chaotic dynamics is governed by interaction of 3 regular singular points in the so-called Borel plane.

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PS02
A Hilbert Space Framework for the Analysis of Bi-

furcations in Control

For the bifurcation analysis in nonlinear parametric optimization one uses a Banach space setting for the smooth bifurcation analysis and a Hilbert space setting for the spectral analysis. In this talk we present a framework addressing both issues and demonstrate how bifurcations arise from a loss of controllability of the linearized dynamical system as well as a second order condition.

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PS02
Use of Parametric Excitation for Unstable Fixed Point Detection and Capture

If a parameter of a deterministic system is intentionally perturbed by small erratic variations, the system may visit unstable orbits distant from the unperturbed attractor. Several mechanisms will be discussed whereby parameter perturbations can lead to distant excursions from the system's unperturbed attractor set, allowing the system to enter the local area of unstable orbits. Once local to the orbit, certain stabilizing linear control strategies can be applied.

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PS02
Lyapunov Transforms and Invariant Stability Exponents

We investigate the conditions under which a Lyapunov transform can yield stability exponents which are coordinate frame invariant. The maximal group of transformations which permit this is shown to be general autonomous linear transformations. The standard Lyapunov exponents are invariant only under rotations, while an eigenvalue decomposition does yield the predicted coordinate invariance. Other possible decompositions of the fundamental matrix are explored numerically.

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PS02
Non-Collision Singularities in a 6 Body Problem

We show the existence of noncollision singularities in a Newtonian 6-body problem. The proof uses the "collision manifold" technique of McGehee and as well as a numerical component in which the unstable manifold of a certain fixed point are carefully traced. The existence of non- collision singularities was recently shown in a 5-body problem. The present work has the advantage that it does not require any small mass ratios as in the previous work.

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PS02
Global Bifurcations in a Reaction-Difussion Model Leading to Spatiotemporal Chaos

The traveling-wave ODE of a two-species reaction-diffusion PDE in one spatial dimension is investigated. It is found that the break-up of a heteroclinic cycle between two fixed points is at the onset of spatiotemporal chaos in the PDE model. This global bifurcation unfolds with two branches of homoclinic orbits, emmanating from the codimension 2 point. In terms of the PDE simulations, we can argue that onset of spatiotemporal chaos corresponds to a stable pulse solution "replaced" by another unstable one.

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